DEVELOPMENT OF A COMPUTER PROGRAM FOR SELECTION OF OPTIMUM MODE OF OPERATION FOR SURFACE MINER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Mining Engineering

BY

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National Institute of Technology
Rourkela-769008
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Rourkela

CERTIFICATE

This is to certify that the thesis entitled **"*DEVELOPMENT OF A COMPUTER PROGRAM FOR SELECTION OF OPTIMUM MODE OF OPERATION FOR SURFACE MINER*"** submitted by Sri Premananda Pradhan, Roll No. 10505006 in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date: **(Kaushik Dey)**

Department of Mining Engineering

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My heart pulsates with the thrill for tendering gratitude to those persons who helped me in completion of the project.

The most pleasant point of presenting a thesis is the opportunity to thank those who have contributed to it. Unfortunately, the list of expressions of thank no matter how extensive is always incomplete and inadequate. Indeed this page of acknowledgment shall never be able to touch the horizon of generosity of those who tendered their help to me.

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An assemblage of this nature could never have been attempted without reference to and inspiration from the works of others whose details are mentioned in reference section. I acknowledge my indebtedness to all of them.

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ABSTRACT

The surface mining of coal and rocks practises drilling and blasting techniques, which requires considerable investments and causes adverse impact on environment and safety. These disadvantages demand introduction of improved technology for blast-free, safe, environment-friendly and economic mining. By continuous research and also experience gained from rock cutting technology with the application of road header and surface miner etc., it has become possible to do mining without blasting by continuous surface miner for hard coal and rocks. Surface miners find their natural applications in projects where drilling and blasting is prohibited or where selective mining of mineral seams, partings and overburden is required. Besides, they offer further advantages like less coal or mineral loss and dilution, improved coal or mineral recovery especially in areas sensitive to blasting, primary crushing, and fragmentation of coal or mineral. Surface miner is proved to be an efficient rock excavation technique in surface mines. However, till date, mining industry is facing a problem in selecting suitable model of surface miner for their own conditions amongst the models available in the market. The readily available models are purchased by the mine authority and then, are deployed in the mines. This results into the increase in mining cost and reduction in performance. The field engineers are also unable to operate the surface miner in the optimum mode of operation. To overcome this, a computer software has been developed to assist the mine management in selecting the most suitable surface miner. For this, an extensive literature review has been carried out to identify the influencing parameters on which the performance of surface miner depends. The available different operating modes and their corresponding production calculation techniques are also studied. This software is developed in C++ and Netbeans (Java Platform). The software has two menus – (1) selection of surface miner and (2) Selection of operating mode. In the software, the suitable surface miner is selected based on the cuttability index developed by Dey and Ghose (2008), which also gives a predicted performance of the selected surface miner. The software is further extended to select the optimum mode of operation to arrive at the maximum possible production. The theoretical production formula as proposed by Dey, 1999 are utilised in this software for calculation of the performance for different operating modes. Performance calculations for four operating modes are possible in the present version of the software. Software is also able to suggest the optimum operating mode (amongst these four). The software is tested for number of cases successfully.

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CHAPTER: 01

INTRODUCTION

1.0 Background:

Archaeological discoveries indicate that mining was conducted in prehistoric times perhaps during Stone Age. The oldest known underground mine in the world was sunk more than 45,000 years ago at Bomvu Ridge in the Ngwenya Mountains, Swaziland, to mine ochre used in burial ceremonies and as body coloring. Iron is dated as early as 2800 BC; Egyptian records of iron ore smelting date from 1300 BC. Great progress in mining was made when the secret of black powder reached the West, probably from China in the late middle Ages. This was replaced as an explosive in the mid-19th century with dynamite, and since 1956 both ammonium nitrate fuel-blasting agents and slurries have come into extensive use. Experience showed that proper placement of holes and firing order is important in obtaining maximum rock breakage in mines. The invention of mechanical drills powered by compressed air increased the capability to mine hard rock, decreasing the cost and time for excavation by several-fold. Developments in drilling were accompanied by improvements in loading methods, from hand loading with shovels to various types of mechanical loaders. Developments took place in surface mining, increasing the volume of production and lowering the cost of metallic and nonmetallic products drastically. Opencast method of mining mineral deposit is the first stage in the history of the development of mining technology. Formerly, only minerals occurring close to the surface or at shallow deposits were mined but now a day's much deeper deposits are worked by opencast mining methods, for The share of production by opencast methods has gone up to over 70% of world's mineral production. The trend all the world over is to construct large open pit coal and lignite mines. There are many mines in different countries which produce over ten million tons of coal per year. In India, too, some mines are being constructed with target production of over ten million tons of coal per year; and it is estimated that the share of opencast coal will rise to 65 per cent by 2010 A.D.

Now-a-days the most popular and economical mining operation is surface mining mainly, due to the following advantages-

- higher production and productivity i.e. higher output per man-shift (OMS),

- greater concentration of operations and simplified management of men and machines,
- lower operating cost,
- shorter gestation period,
- possibility of mining lower grade of coal seams economically,
- possibility of high degree of mechanization and rationalization,
- greater safety and better working conditions, and
- simplified engineering, planning and control.

The surface mining of hard coal and rocks requires drilling and blasting of the strata. Blasting has adverse environmental impacts and needs utmost care to carry out safely. These disadvantages demand introduction of improved technology for blasting-free, safe, eco-friendly and economic mining.

Before 1970s, rock cutting was not experienced widely. However, in 70s and 80s, rock cutting equipments like bucket wheel excavator, surface miner, road header etc, were used extensively and were gained popularity. In India, surface miner was introduced in the year 1996. Surface miner is so popular that now 400 surface miners is in operation around the world and amongst which India is using 105 within this short span of time. For economic extraction, strategic deployment of surface miner is required. For best profit suitable surface miner and its mode of operation should be chosen.

1.1 Objective:

The basic objective of the project is to develop a computer program for selection of optimum mode of operation for surface miners and to check whether surface miner is applicable or not.

1.2 Research Strategy:

I. Extensive literature review has been carried out to identify the parameters affecting performance of surface miner. The role of these parameters and how they are affecting the performance of surface miner has been established.

II. The exact mathematical and logical relationship between this parameter and mode of operations are determined. Then a computer program in C is developed and the program is tested with actual field data.

III. To make the software more users friendly the software has been developed with the help of Net Beans which also improved the looks of the software

IV. To check whether the software is working or not several field data has been tested successfully.

CHAPTER: 02

LITERATURE REVIEW

OPERATING MODES

FACTORS AFFECTING PERFORMANCE OF SURFACE MINER

SPECIFICATION OF SURFACE MINER

SELECTION OF OPERATING MODE – MANUFACTURER APPROACH

CHAPTER: 02

LITERATURE REVIEW

2.0 INTRODUCTION

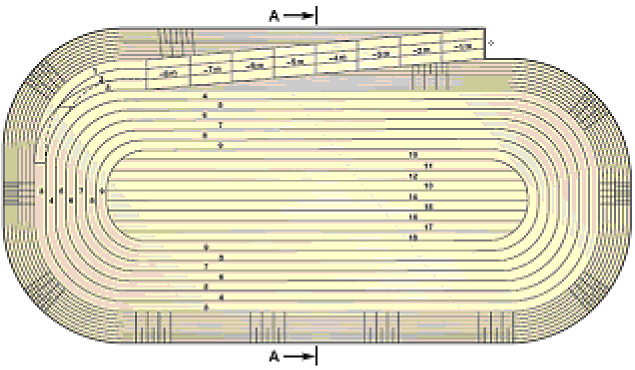
Literature review has been carried to find out the existing mode of operation of surface miner, the parameters affecting performance of surface miner and specification of surface miners.

2.1 OPERATING MODES

Surface miner can be deployed in different ways based on the onsite requirement. Some of the possible variations in operating mode are discussed in the following sections –

2.1.1 Harvesting/continuous mode

In the harvesting mode (Fig. 2.1), the Surface Miner operates on an even field and continuously cuts the material. The cutting process can thus be continued also during driving a curve with the machine.



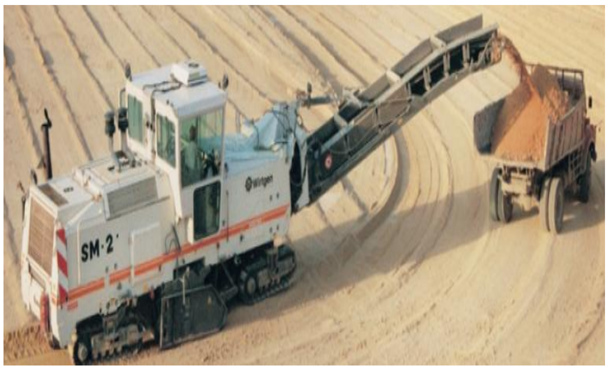


Fig. 2.1 – Harvesting/continuous mode of operation using surface miner

The mining area is developed by cutting slice by slice. For each slice the cutting depth only needs to be set once on the Surface Miner.

Production for continuous mode of operation:

In windrowing mode $P = \frac{S \times V \times D \times W \times 60}{1000}$

In conveyor loading $P = \frac{S \times D \times \frac{W \times 60}{1/V + Tc/Lt}}{1000}$

Where

W= Working hour

D=Cut depth

S= Cutting drum width

V= Cutting speed

Tc= Truck exchange time

Lt= Length of cut to fill a truck

2.1.2 Empty travel back mode

In Empty travel back mode (Fig. 2.2), the surface miner moves in backward direction without cutting the bench after completion of cutting one strip. Reaching the starting line, it adjusts itself to cut the adjacent strip. This is generally adopted under the following conditions:

- the available pit length is so less that the turning time becomes more than empty travel back time,
- pit condition and dimensions are not suitable for turning of the machine.

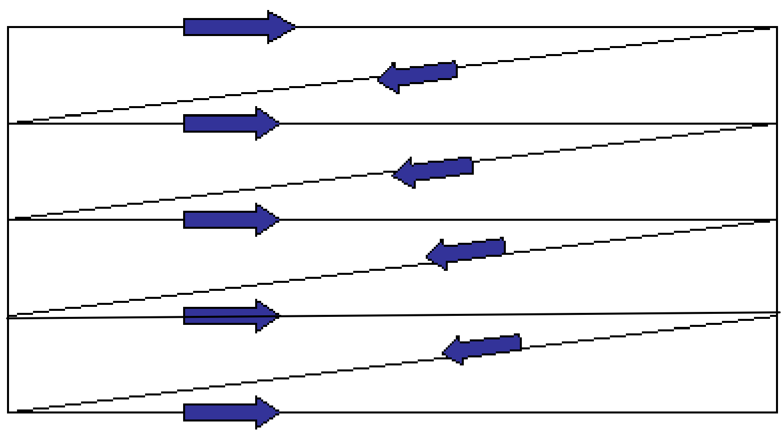


Fig. 2.2 - Empty travel back mode of operation using surface miner

- Production for Empty travel back & conveyor loading[3]

$$p = \frac{S \times D}{1000}\left(\frac{60}{1/_{Vc} + 1/_{Ve} + Tc/_{Lt}}\right)$$

- Production for Empty travel back & windrowing

$$p = \frac{S \times L \times D}{1000}\left(\frac{60}{L/_{Vc} + L/_{Ve}}\right)$$

Where

S=Drum width,

Lt=Length of cut to fill a truck,

Tc=Truck exchange time,

D=Cut depth,

L=Effective face length,

Vc=Cutting speed,

Ve=Empty travel speed.

2.1.3 Turn back mode

In turn back mode (Fig. 2.3), after the end of cutting one strip, the cutting drum of the machine is raised. Then, the machine turns back and set at the adjacent strip for the next cut. This is most widely accepted and used method as it gives more production. This method is generally adopted for a mine with following condition:

- large pit length is available,
- pit condition and dimensions allow the machine to turn back conveniently.

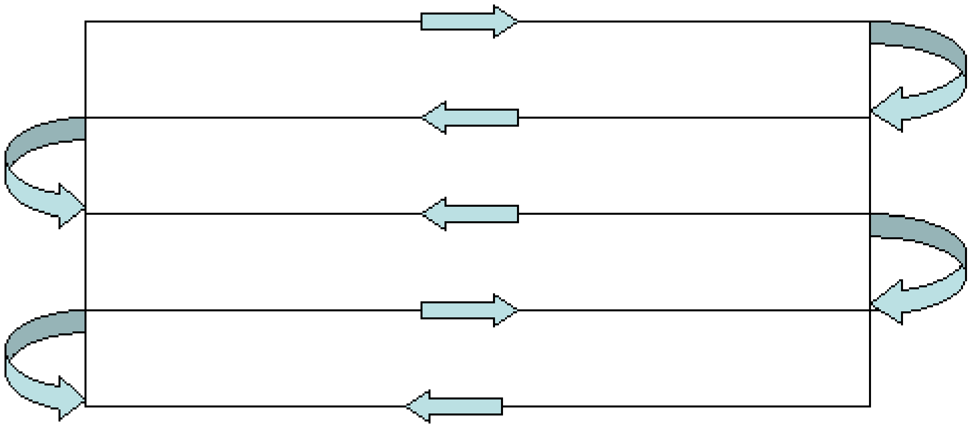


Fig. 2.3 Turn back mode of operation using surface miner

- Production for Turn back & conveyor loading

$$p = \frac{S \times D}{1000}\left(\frac{60}{1/_{Vc} + {}^{Tt}/_{L} + {}^{Tc}/_{Lt}}\right)$$

- Production for Turn back & windrowing

$$p = \frac{S \times L \times D}{1000}\left(\frac{60}{L/_{Vc} + Tt}\right)$$

Where

S=Drum width,

Lt=Length of cut to fill a truck,

Tc=Truck exchange time,

D=Cut depth,

L=Effective face length,

Vc=Cutting speed,

Tt=Turning time

2.1.4 Block operation with ramp cutting

Surface Miners can be integrated into existing mines and quarries using conventional drilling and blasting operations in benches. They are able to continue to work on the existing benches, using the block method.

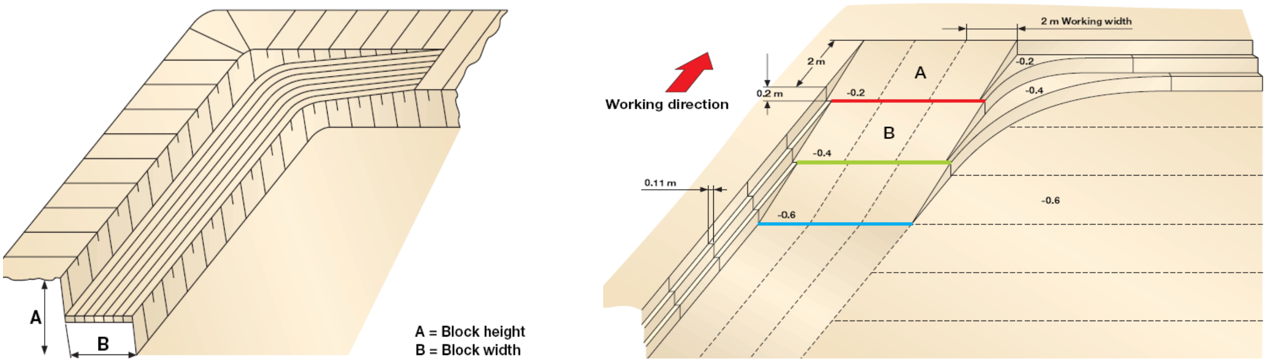


Fig. 2.4 –Ramp cutting using surface miner

While cutting the block down to its planned level, the surface miner can also cut its own ramp[4]. After completing the first cut, the next cut can be started adjacent to the first one. Since turning on narrow benches is difficult and time consuming, two alternative operations can be recommended, viz., turning back at an appropriate area outside the ramp and empty travel back.

Typical ramps require a gradient of approx. 10-15% to allow movement of the tyre vehicle. Most of the commercially available surface miners are able to cut its' own ramp both in upwards or downwards (Fig. 2.4).

2.1.5 Operation in an open cut

Depending on the length and the width of the open cut, surface miner can be either turned at the end of each cutting path or driven rearwards to start the next cut on the same side of the area as the previous one (Fig. 2. 5.a).

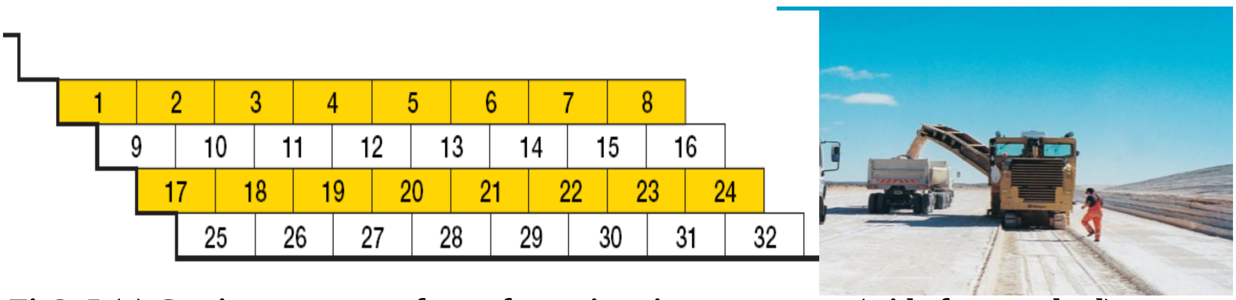


Fig2. 5 (a) Cutting sequence of a surface miner in an open cut (wide face method).

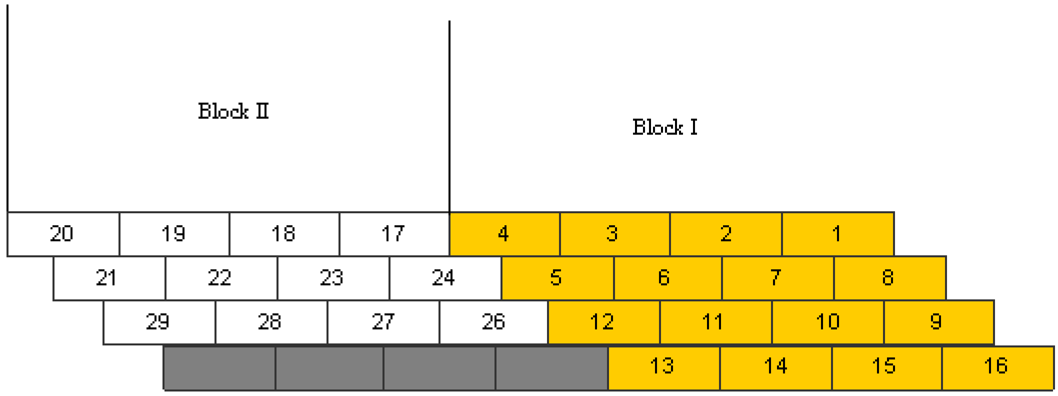


Fig. 2.5(b) – Block mining method

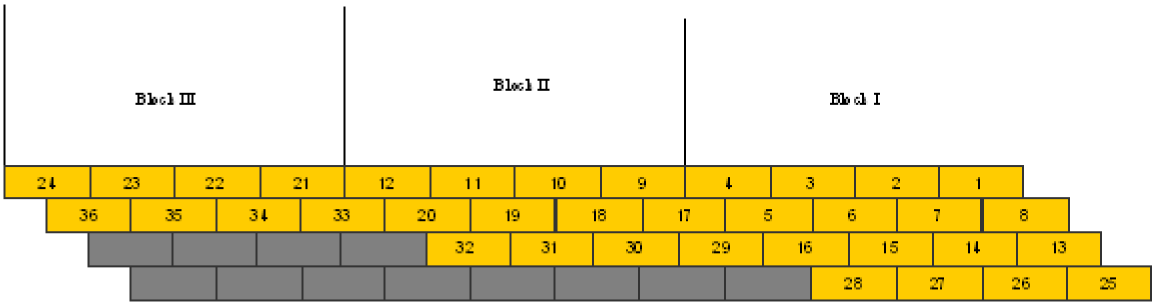


Fig. 2.5(c) – Step cut method

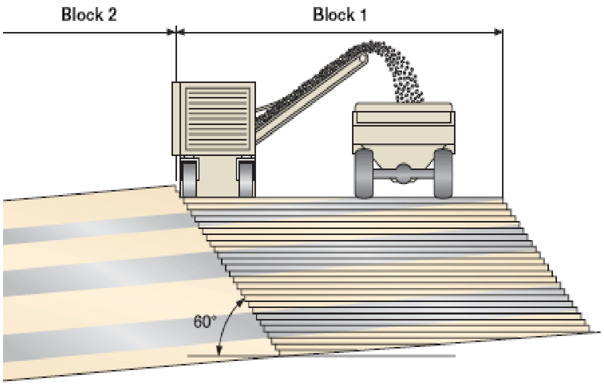
2.1.6 Special operations

The position of the cutting drum in the middle of the machine and the working characteristics such as continuous cutting, precise cutting depth control, cutting even and stable surfaces of a Surface Miner allow to work in various conditions, thus providing technical solutions for many demanding tasks in mining.

2. 1.6.1 Selective mining of inclined seams

Depending on the degree of inclination of the seams different working methods are possible:

Slightly inclined seams can be cut in blocks as shown in the adjacent drawing. When cutting at the boundary between coal and waste, a certain degree of dilution of the material has to be considered. Cutting very steep seams or pockets of pay material can be mined as shown on the Fig. 2.6(a) & Fig. 2.6(b).



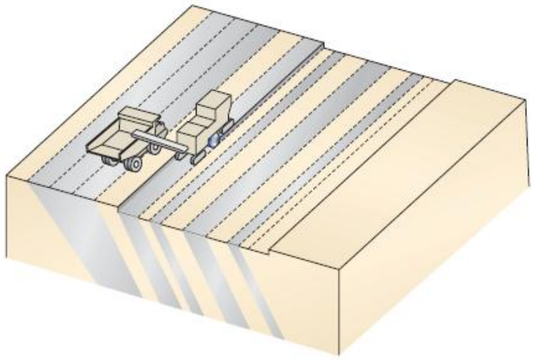


Fig. 2.6 (a) Slightly inclined seams   Fig. 2.6 (b) Steeply inclined multiple seams

2. 1.6.2 Blending material while cutting on a ramp

Irregular deposits often require the blending of material in order to maintain quality standards either for the following process or for the production of market-oriented mineral lends. Horizontally variations of the deposit can be blended with Surface Miners directly during cutting. The machine cuts continuously on a ramp, thus mining through all layers and homogenizing the material. Subsequently the requirements for mixing plants are minimized.

2.1.6.3 Cutting steep highwall slopes

Miners can produce steep highwall slopes. Generally, Surface Miner achieve a slope angle of 60° in normal operation. Under certain circumstances even higher angles have been achieved as shown in fig. 2.7.

Fig. 2.7 Cutting steep highwall slopes

2.2 FACTORS AFFECTING PERFORMANCE OF SURFACE MINER

Performance of a surface miner, generally, depends on cutting in edges, curves, turning radius, length of working area and machine configuration, which are controllable parameters. However, rock mass is a natural component in the earth's crust and is thus immutable. The parameters, affect the performance of surface miner significantly, are discussed in the following section –

2.2.1 Operating conditions -Cutting in edges and curves, turning, turning radius

For sharp turns, the cutting drum has to be lifted in order to achieve a small turning radius. However, the machine can also turn while the cutting drum is still in operation. As a rule of thumb the turning, the turning radius is:

12 × cutting width (when cutting harder rock, the cutting depth has to be reduced).

The radiuses which can be achieved depend amongst other factors on the material to be cut and the actual depth of the cut. Generally, they can only be determined precisely during the first operations in a deposit. Thus, it is possible to achieve smaller or larger radii in practice.

2.2.2 Geometrical factors- Length of working area

The productivity of a surface miner depends on the length of the available working area. Longer cuts will enhance the productivity, because only a smaller amount of time is spent in manoeuvring from one cut to the next. The forward speed and travel time for a given cutting length furthermore depends on number of factors:

• Cutting depth

• Material hardness and structure

• Type of machine and installed engine power

Therefore, the graph below only can show the general relation between effective production and cutting field length.

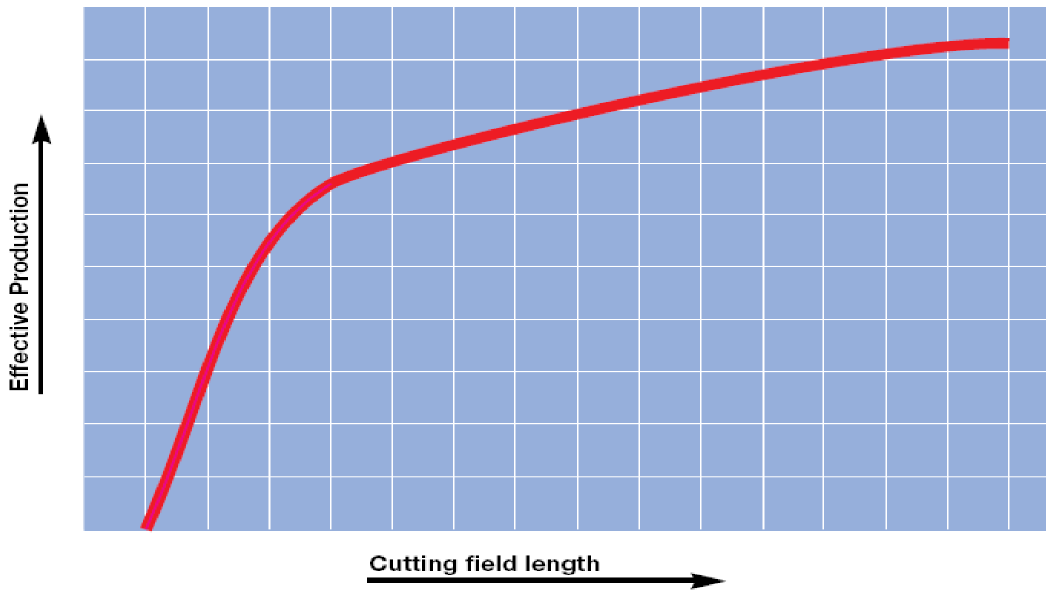


Fig. 2.8- Cutting field length vs. effective production

The graph (Fig. 2.8) shows that as the cutting field length increases the effective production increase rapidly to certain extent after that it increases slowly. In standard applications, the appropriate minimum cutting field length should be in the range of:

• 100 m (hard material, low forward speed)

• 300 m (softer material, high forward speed)

2.2.3 Rock mass parameters

Performance of surface miner depends on various factors among them rock mass parameter is a vital factor because it is depends on natural occurrence. Rock mass parameters includes Moisture content, density, brittleness, unconfined compressive strength, point load index, Young's modulus, fracture energy, toughness index, Brazilian tensile strength, sonic velocity, abrasivity (Schimazek-F, Cerchar) volumetric joint count, stickiness of material and specific energy of cuttability some of the impartment parameters are discussed as follows:-

2.2.3.1 Moisture content

As the moisture content increases the performance of surface miner decreases because of the wearing effect of the rock.

2.2.3.2 Density

As the density of rock increases the performance decreases because drum speed decreases.

2.2.3.3 Unconfined compressive strength (UCS)

Cutting performance of surface miner mainly depends on UCS of rock. As the UCS increases performance of surface miner decreases. If UCS is more than the cutting capacity of surface miner may not able to cut the material.

2.2.3.4 Point load index

Performance of surface miner also depends on point load index of the rock mass for more point load more energy is required.

2.2.3.5 Fracture Energy

For greater performance more energy is required because rock mass required more energy to fracture.

2.2.3.6 Brazilian tensile strength

If the Brazilian tensile strength is more, the rock required more energy to break hence the performance of surface miner decreases.

2.2.3.7 Abrasivity

If the abrasivity increases there will be decrease in performance of surface miner.

2.2.3.8 Cuttability

Performance of surface miner depends on cuttability index, as the cuttability index increases performance of surface miner decreases. If the cuttability index exceeds greater than 80 surface miner should not be deployed.

2.2.4 Machine configuration

Performance of surface miner depends on machine configuration such as cutting tool configuration (rake angle, attack angle, clearance angle and tip angle, pick lacing, type of pick (point attack) number of picks, tip material), drum weight, drum width, engine power, nature of coolant for tips. Some of the impartment parameters are discussed as follows:-

2.2.4.1 Rake angel

Rake angel is the angel between the pick and the surface. The rake angel should not exceed 5˚ for maximum production.

2.2.4.2 Clearance angle

For maximum production the clearance angle should not exceed more than 25˚.

2.2.4.3Types of picks

Performance of surface miner also depends on types of picks. If the hardness and sharpness of picks are more than performance of the surface miner is more.

2.2.4.4 Number of picks

If the numbers of picks increases, pressure on single picks decreases, hence the performance of surface miner increases.

2.2.4.5 Drum weight

As the drum weight increases pressure on rock due to weight of drum increases, hence performance of surface miner increases.

2.2.4.6 Drum width

Performance of surface miner increases along with increase in drum width because it will cut more material in lesser amount of time.

2.2.4.7 Engine power

If engine power is more performance of surface miner is more.

2.2.5 Loading Options

The surface miner range offers the following loading and material handling options (Fig. 2.9):

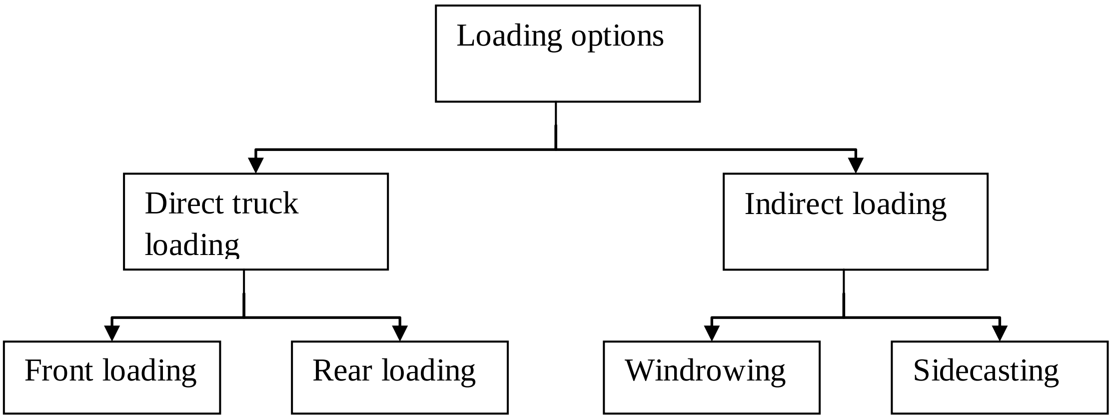


Fig. 2.9- Loading option

2.2.5.1 Direct loading onto trucks

One of the main characteristics of the surface miners is their ability to load the cut material directly onto trucks. Depending on the machine type, surface miners are designed either as front loading or rear loading machines.

2.2.5.1.1 Front loading

The surface miner with the discharge conveyor mounted in front of the machine can go for front loading. The conveyor can be slewed of the right and the left and the height is adjustable. Depending on the truck size, these machines load the trucks either from behind (Fig. 2.10) or from the side (Fig. 2.11). The surface miner's operator has a direct view on the truck.

Fig. 2.10- Front loader – loading from behind   Front loader – loading from the side

In market rear loading with discharge conveyor mounted type of surface miners is also available. The conveyor can be slewed of the right and the left and the height is adjustable. The weight of the conveyor is balanced by a counter weight. The surface miner's operator has direct visual contact to the truck because he may slew his seat to the right or left hand side.

Fig. 2.11-Rear loader - loading from the side   Rear loader - loading from the side

2.2.5.1.2 Smooth loading of trucks with fine material

In all cases, the fine gradation of the material cut by a surface miner ensures a smooth, continuous and complete loading of the truck body. The loading characteristics allow flexibility when choosing a suitable truck size. For example, under certain circumstances trucks with aluminium truck body and enhanced payload can be used.

2.2.5.1.3 Truck exchange

To enhance productivity and to minimize waiting time for the surface miner an empty truck should be waiting beside the machine just before the presently loaded truck is completely filled. The normal truck exchange times are between 15-30 seconds, depending on the type of the surface miner and the size of the truck. The exchange times are also affected by the available area for manoeuvring of the trucks and the driver's experience.

2.2.5.1.4 Advanced truck exchange

For surface miners with a front loading system the empty truck positions (Fig 2.12) itself parallel to the presently loaded truck. The loading of the second truck starts by simple swinging of the conveyor only. Stopping the cutting process is not required. The following sequence shows a perfect truck exchange while the surface miner continuously goes on with cutting.

Fig 2.12 Truck no. 1 is being loaded, truck no. 2 is positioning. Surface Miner slews its conveyor from Truck no. 1 to no. 2,

2.2.5.2 Indirect loading

Sidecasting of the material Sidecasting the material means that a stockpile is built by dumping the material from different cuts via the conveyor on one pile (Fig.7). Depending on the slewing angle of the conveyor, up to 3 to 5 adjacent cuts can be dumped on top of each other. Due to the height of the formed stockpile, the material can easily be reloaded with a front-end loader.

2.2.5.2.1 Advantage:

The cutting operation of the surface miner using Side casting is independent from the truck loading operation.

2.2.5.2.2 Side casting mode

In side casting mode surface miner cuts the material and a stockpile is built by dumping the material from different cuts via the conveyor on one pile. Depending on the slewing angle of the conveyor, up to 3 to 5 adjacent cuts can be dumped on top of each other. Due to the height of the formed stockpile, the material can easily be reloaded with a front-end loader.

Fig. 2.13 - 2500 SM – side cast mode

2.2.5.2.3 Windrowing

In windrowing mode the cut material is directly discharged behind the machine without using a conveyor. Therefore the cutting operation is independent from the truck loading operation, but the material has to be re-handled with a front-end loader.

Fig. 2.14 - Surface Miner – windrow operation Surface Miner – windrow operation

For many applications, the higher productivity in the windrow operation in comparison to direct loading over-compensates for the additional cost for the re-handling of the material (e.g. wheel loader). In addition, no belt wear and no operating cost for the conveyor will arise when working in the windrowing mode (Fig. 2.14).

Table: - 1 Comparison of the different loading methods:

	ADVANTAGES	**DISADVANTAGES**
Direct Loading	No re-handling of material required	Larger working area required for truck manoeuvring Production affected by truck exchange time Belt wear
Sidecasting	Blending of materials in the mine Stockpile of material in the mine No waiting for trucks, independent operation	Restricted to 3-5 cuts wide on each side of the mine stockpile Belt wear Material has to be re-handled Material prone to absorb water when lying on the ground
Windrow	No waiting for trucks No belt wear / higher availability Higher production rates than conveyor loading Coarser material Better selectivity on steep inclined seams	Large working area required Material has to be re-handled either by loader or scraper Material prone to absorb water when lying on the ground

2.3 SPECIFICATION OF SURFACE MINER

Different types of surface miners[8] available in the market and some old models are as follows and details specifications are given in Table 2 :

Wirtgen (Model no. SM2100, SM 2200, SM 2500,SM 3700, SM 4200),L&T (Model no.KSM304 & KSM 223), Trencor 3000SM,Takraf[5] (Model no. MTS 180, MTS 300, MTS 500, MTS800, MTS1250, MTS2000), Bitelli (Model no.SF202 M), and Vermeer[9] (model n0. T855, T955, T1055, T1225). Among these Wirtgen is the pinner manufacturer of surface miners.

Table:-2 Specification of different models

	Parameters	Drum width (m)	Machine power (kW)	Operating weight (ton)	Rated capacity (m^3/h)	Cutting depth (mm)	Maximum cutting speed (m/min)	Operating gradient (1 in x)
Wirtgen GmbH	SM 2100	2.0	448	41	550	250	25	6
	SM2200	2.2	671	49	668	350	84	6
	SM2500	2.5	783	100	845	600	25	7
	SM3500	3.5	895	137	1900	470	25	12
	SM4200	4.2	1194	184	2400	600	20	5
Vermeer	T855	2.5	281	40.8	NA	812	28	NA
	T955	3.4	309	56.7	NA	812	20	NA
	T1055	3.4	317	61.2	NA	812	16	NA
	T1255	3.7	447	99.8	NA	610	12	NA
L & T	KSM223	2.2	597	NA	NA	350	83	8
	KSM304	3.0	895	100	NA	400	20	5
TAKRAF GmbH	MTS180	3.3	500	NA	180	700	NA	NA
	MTS300	4.0	750	NA	300	875	NA	NA
	MTS500	4.9	1650	NA	500	1050	NA	NA
	MTS800	5.6	2000	NA	800	1225	NA	NA
	MTS1250	6.5	2500	NA	1250	1400	NA	NA
	MTS2000	7.4	2500	NA	2000	1575	NA	NA
Bitelli	SF202	2.0	515	43	180	250	NA	NA

2.4 SELECTION OF OPERATING MODE – MANUFACTURER APPROACH

User of the surface miners always finds difficulty in planning the operating mode of surface miner in short term (day to day operation) and long term basis (for a particular face). For the ready guidance to them, surface miner manufacturer provides performance graphs derived based on their experience. Though, the reliability of these charts varies due to two reasons: (a) manufacturer assumes ideal conditions (b) geo-mining differences in applications. Further, these charts are also not available for all the manufacturers. The selection of optimum mode of operation concept is very complex and needs larger time for hand calculation. So it was felt to establish a user friendly computer program to assist the field engineer to arrive at the optimum mode of operation and production calculation.

2.4.1 Production estimate

The figures (Fig.9) in the production charts[5] are based on cutting performance without downtimes for manoeuvring the machine etc. They are based on 100 % efficiency (e.g. sufficient number of trucks).

Drums with a tool spacing of 35-50 mm are considered for materials with a compressive strength (UCS) of 25-80 MPa. Materials with UCS values > 80 MPa are only to be cut under certain circumstances (fractured material). For materials with a UCS < 25 MPa, cutting drums with 90 mm tool spacing are considered.

The maximum curves represent operation under ideal conditions only. The assumptions are: weathered rock, horizontally laminated or heavily fractured rock (fractures in different directions with max. 5 cm distance). The minimum curve represents cutting performance in solid rock or benches with only little amount of fractures (distance of fractures 0.5-1 m).

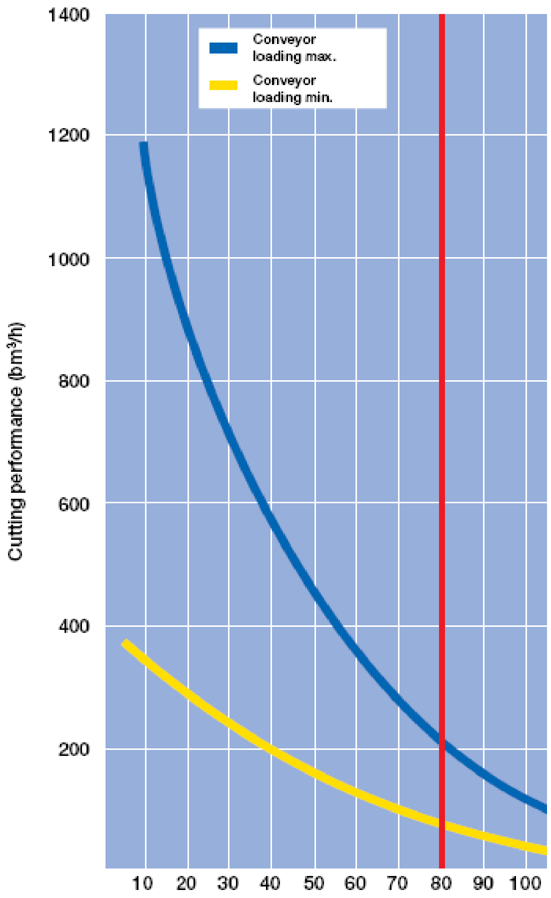
2.4.2 Production range (cutting performance)

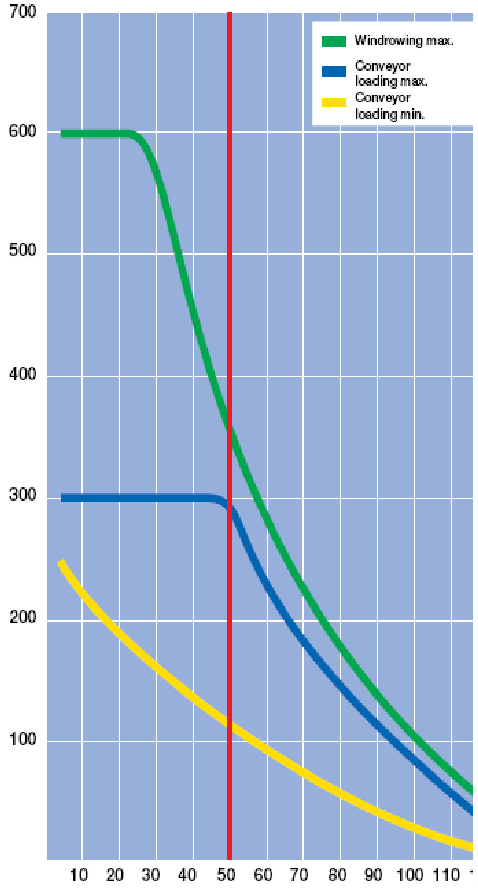
Wirtgen GmbH has provided performance curve which shows the cutting performance ($bm^{3/}h$) of the machine with respect to UCS of the rock. Some time these cutting performances depend on the abrasivity volumetric joint count, and stickiness of material which are rock parameters.

The performance curve which is provided by the Wirtgen GmbH is plotted between cutting performance ($bm^{3/}h$) and UCS of the rock.

Wirtgen GmbH has provided such curves for its different model as given below.

Production range (cutting performance) of the Wirtgen Surface Miner 2500 SM and 2200





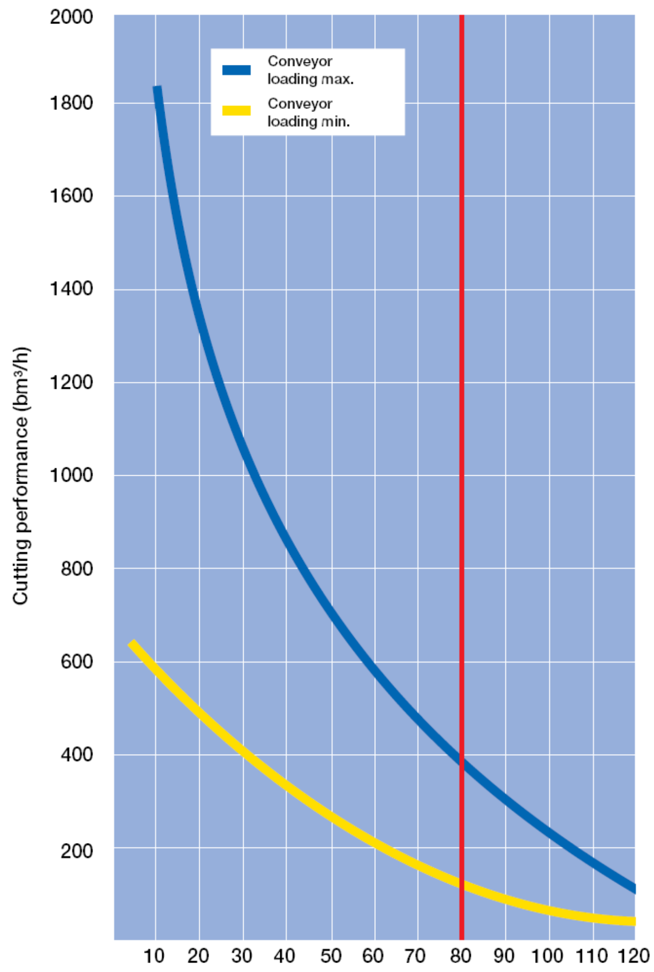
UCS (MPa)

Fig. 2.15 For SM 2500 Wirtgen Surface Miner Fig. 2.16 For SM 2200 Wirtgen Surface Mine

(a)) Material with a hardness >80 MPa can only be cut under certain conditions. As the UCS increases the production decreases at 80 MPa conveyors loading max. decreases to 200te, and conveyor loading minimum decreases to 50T

(b) Material with a hardness >50 MPa can only be cut only under certain conditions. As the UCS increases the production remain constant for windrowing method up to 25 MPa. After it will fall gradually. In case of conveyor loading production remain constant up to 50 MPa. In conveyor loading minimum production goes on decreasing with increase in UCS.

Production range (cutting performance) of the Wirtgen Surface Miner 3700 and 4200 SM



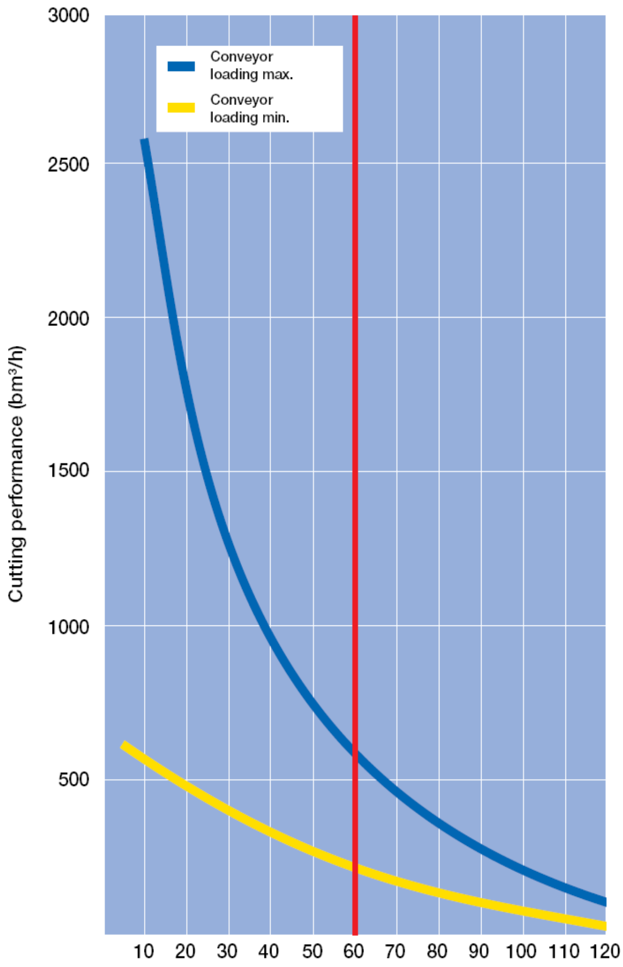


Fig. 2.17 For SM 3700 Wirtgen Surface Miner **Fig. 2.18 For SM 4200 Wirtgen Surface Mine**

(c) Material with a hardness >80 MPa can only be cut under certain conditions. As the UCS increases the production decreases at 80 MPa conveyor loading max. decreases to 400te, and conveyor loading minimum decreases to 100T.

(d) Material with a hardness > 60 MPa can only be cut under certain conditions. As the UCS increases to production decreases sharply after 1000 Tones it decreases gradually up to 60 MPa. In case of conveyor loading minimum it decreases gradually

CHAPTER: 03

SELECTION OF SURFACE MINER

FACTORS AFFECTING SELECTION OF SURFACE MINER

CUTTABILITY INDEX

CHAPTER: 03

SELECTION OF SURFACE MINER

3.1 FACTORS AFFECTING SELECTION OF SURFACE MINER

Selection of surface miner depends on cuttability index, as the cuttability index increases performance of surface miner decreases. If the cuttability index exceeds 70 surface miner should not be deployed. “Cuttability” of a surface miner depends on a number of influencing parameters. These parameters can be categorized as rock/rockmass parameters, machine parameters and the type of application. The properties relevant to the classifications are detailed in Table 3..

Table 3 - Parameters influencing selection of surface miner [2]

Rock/rockmass parameters	Machine configuration	Type of Application
Moisture content, density, brittleness, unconfined compressive strength, point load index, Young’s modulus, fracture energy, toughness index, Brazilian tensile strength, sonic velocity, abrasivity (Schimazek-F, Cerchar) volumetric joint count, stickiness of material, specific energy of cuttability	Cutting tool configuration (rake angle, attack angle, clearance angle and tip angle, pick lacing, type of pick(point attack) number of picks, tip material), drum weight, engine power, nature of coolant for tips	Mode of operation (windrowing/ conveyor loading), length and width of operating area (select machine travel method), operator skill, specific requirements (dry/wet, fragmentation desired and output)

Rockmass is a natural component in the earth’s crust and is thus immutable. Machine configuration is the one time decision of the mine management. Thus, performance of a surface miner, generally, depends on cutting in edges, curves, turning radius and length of working area, truck changing time, which can be controlled by the field engineers. Field engineer can choose operating modes of surface miner to achieve the maximum production based on the onsite requirement. The operating modes can be classified based on the travelling and loading options. The possible modes of operation are depicted in Fig. 3.

User of the surface miners always finds difficulty in selecting suitable machines (for a mine) and also in choosing their operating mode in short term (day to day operation) and long term basis (for a particular face). For the ready guidance to them, surface miner manufacturers provide performance graphs (Performance vs compressive strength) derived based on their experience. Though, the reliability of these charts varies due to two main reasons: (a) manufacturer assumes ideal conditions (b) geo-mining differences in applications. Further, these charts are also not available for all the manufacturers to overcome this problem.

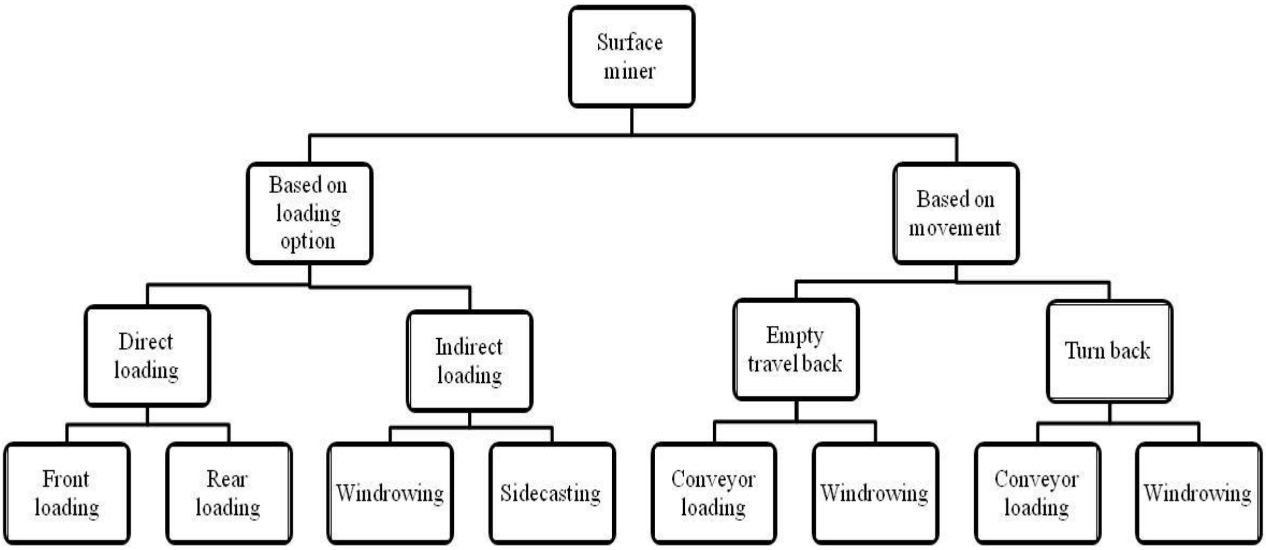


Fig. 3.1 – Possible modes of operation of a surface miner

3.2 CUTTABILITY INDEX [1]

"Cuttability index" developed by Dey and Ghose (2008) has been utilised in selection of surface miner model. The model has considered the key influencing parameters, namely, point load strength index, rock abrasivity, volumetric joint count, direction of machine operation with respect to joint direction and the cutting power of surface miner. The ratings of these parameters are tabulated in Table 2.

Utilising this theory software has been developed in C language to select the suitable surface miner model (for testing purpose). The flow sheet of the software is given in Fig. 4.2. Similarly, the mathematical relationship proposed for computation of surface miner performance in different operating mode is utilised for selecting the optimum operating mode of surface miner. The flow sheet for this module is given in Fig. 4.

Thus, the cuttability index (*CI*) is the sum of the rating of above five parameters

$$CI= I_s+Jv+ Aw+ J s+M \qquad (1)$$

This cuttability index gives a firsthand idea about the "GO – NO GO" criterion on applicability of surface miner. Production rate of a surface miner can be estimated as follow –

$$L^* = \left(1 - \frac{CI}{100}\right) kM_c \qquad (2)$$

Where,

L^* = production or cutting performance (bcm/h)

Mc = Rated capacity of the machine (bcm/h)

CI = cuttability index

k = a factor for consideration of influence of specific cutting condition and is a function of pick lacing (array), pick shape, atmospheric condition etc. and varies from 0.5 – 1.0.

Table 3.2 – Rating of the parameters of new rockmass cuttability classification

Class	**I**	**II**	**III**	**IV**	**V**
Point load index (Is50) Rating (Is)	< 0.5 5	0.5 – 1.5 10	1.5 – 2.0 15	2.0 – 3.5 20	> 3.5 25
Volumetric joint count (no/m3) Rating (Jv)	> 30 5	30– 10 10	10 – 3 15	3 – 1 20	1 25
Abrasivity Rating (Aw)	< 0.5 3	0.5 – 1.0 6	1.0 – 2.0 9	2.0 – 3.0 12	> 3.0 15
Direction of cutting respect to major joint direction Rating (Js)	720 - 900 3	540 - 720 6	360 - 540 9	180 - 360 12	00 - 180 15
Machine power (kW) Rating (M)	> 1000 4	800 – 1000 8	600 – 800 12	400 – 600 16	< 400 20

CHAPTER: 04

DEVELOPMENT OF COMPUTER PROGRAM

FLOW CHATS

NETBEANS

THE SOFTWARE (S.M 1.0)

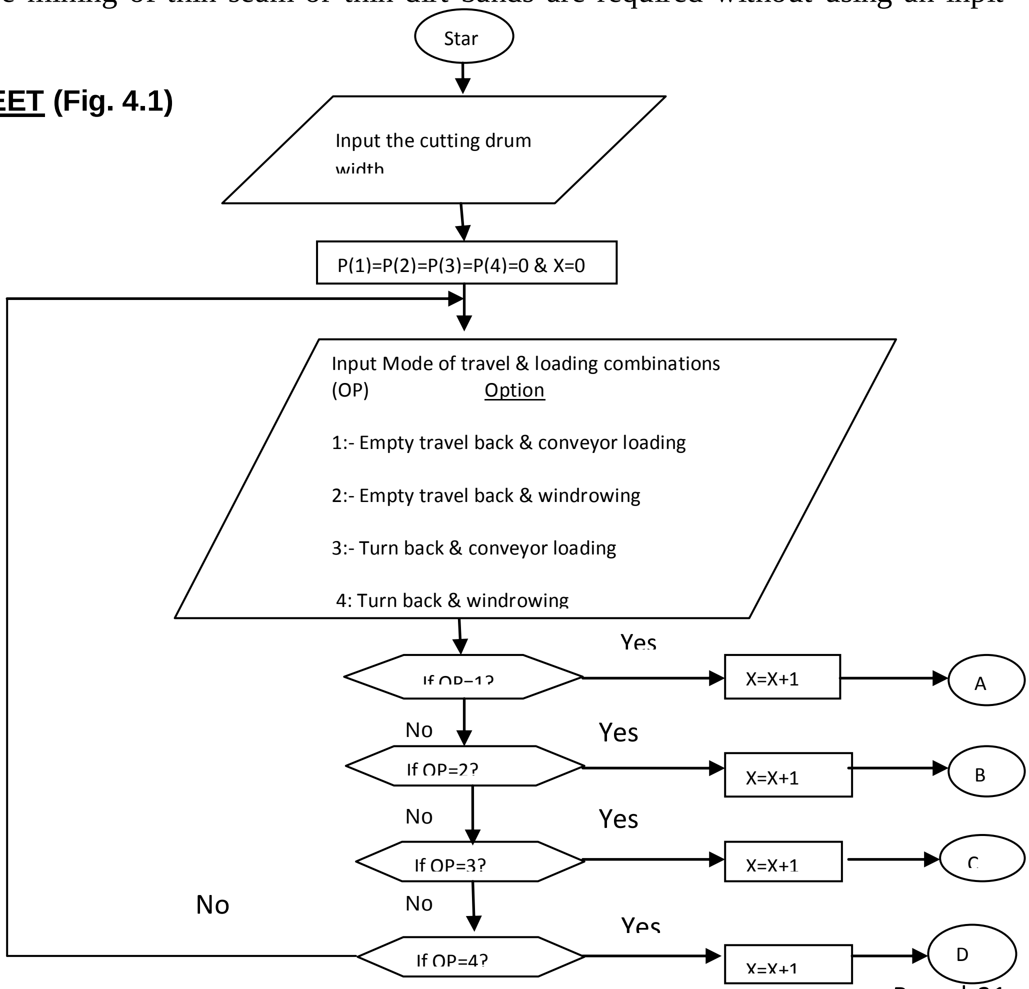
CHAPTER: 04

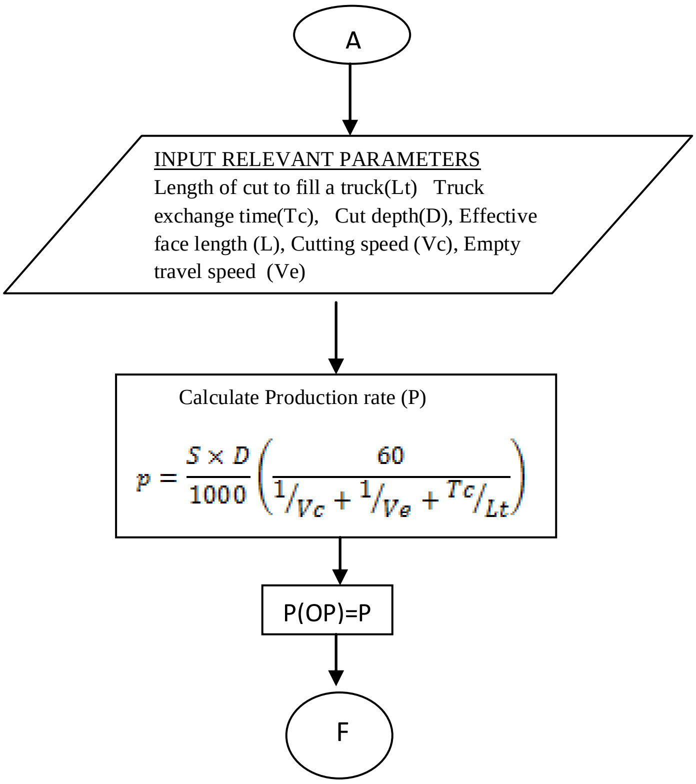
DEVELOPMENT OF COMPUTER PROGRAM

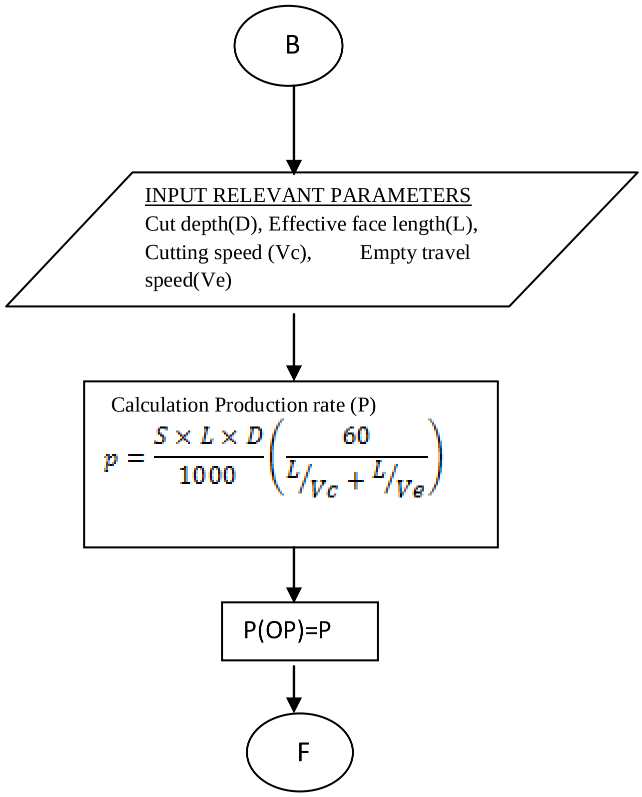
From the lecture review we observed and a computer algorithm has a software has been developed to assist the field engineers to select suitable surface miner and its operating mode. The software is presently under development and only a part of it is completed. The developed module can select the operating mode for the surface miner to achieve optimum production under following geo mining conditions:-

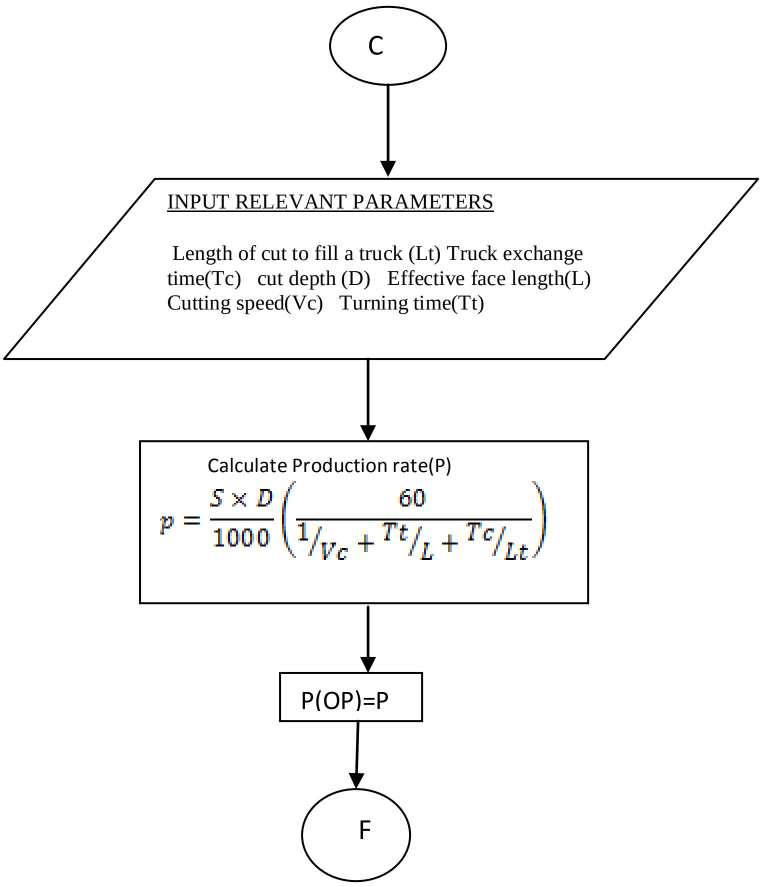
- Compressive strength of the material should be less than 120 MPa and the rate of compressive strength to tensile strength should be preferably less than 10.
- The gradient of the working bench should be flat or very gently inclined.
- The cutting material should be non sticky and the rock should be non-abrasive
- The available pit length is very less or large pit length is available
- Pit condition and dimensions are not suitable for turning of the machine
- Pit condition and dimensions allow the machine to turn back conveniently.
- Blasting is prohibited for environmental or other reasons.
- Selective mining of thin seam or thin dirt bands are required without using an inpit crusher.

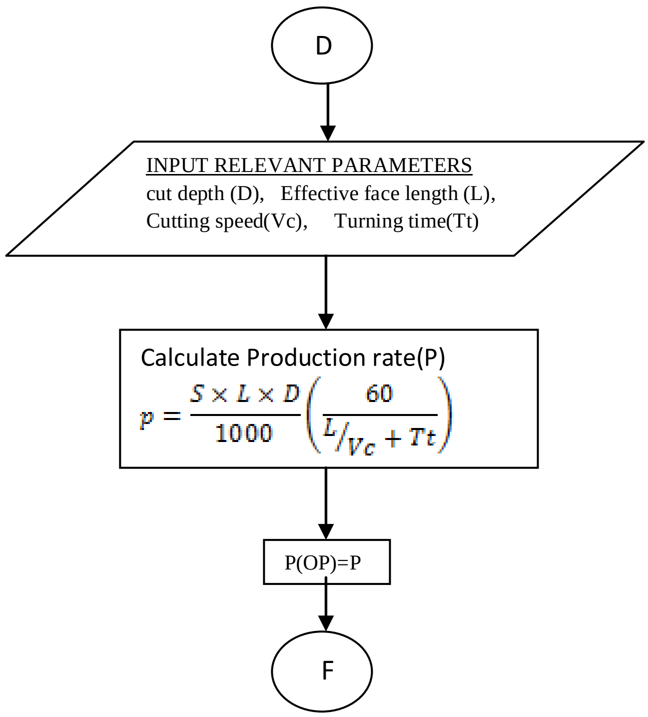
<u>4.1 FLOW SHEET</u> (Fig. 4.1)




A
INPUT RELEVANT PARAMETERS
Length of cut to fill a truck(Lt) Truck exchange time(Tc), Cut depth(D), Effective face length (L), Cutting speed (Vc), Empty travel speed (Ve)
Calculate Production rate (P)
$p = \frac{S \times D}{1000}\left(\frac{60}{1/_{Vc} + 1/_{Ve} + Tc/_{Lt}}\right)$
P(OP)=P
F


B
INPUT RELEVANT PARAMETERS
Cut depth(D), Effective face length(L), Cutting speed (Vc), Empty travel speed(Ve)
Calculation Production rate (P)
$p = \frac{S \times L \times D}{1000}\left(\frac{60}{L/_{Vc} + L/_{Ve}}\right)$
P(OP)=P
F


C
INPUT RELEVANT PARAMETERS
Length of cut to fill a truck (Lt) Truck exchange time(Tc) cut depth (D) Effective face length(L) Cutting speed(Vc) Turning time(Tt)
Calculate Production rate(P)
$p = \frac{S \times D}{1000}\left(\frac{60}{1/_{Vc} + Tt/_{L} + Tc/_{Lt}}\right)$
P(OP)=P
F


D
INPUT RELEVANT PARAMETERS
cut depth (D), Effective face length (L), Cutting speed(Vc), Turning time(Tt)
Calculate Production rate(P)
$p = \frac{S \times L \times D}{1000}\left(\frac{60}{L/_{Vc} + Tt}\right)$
P(OP)=P
F

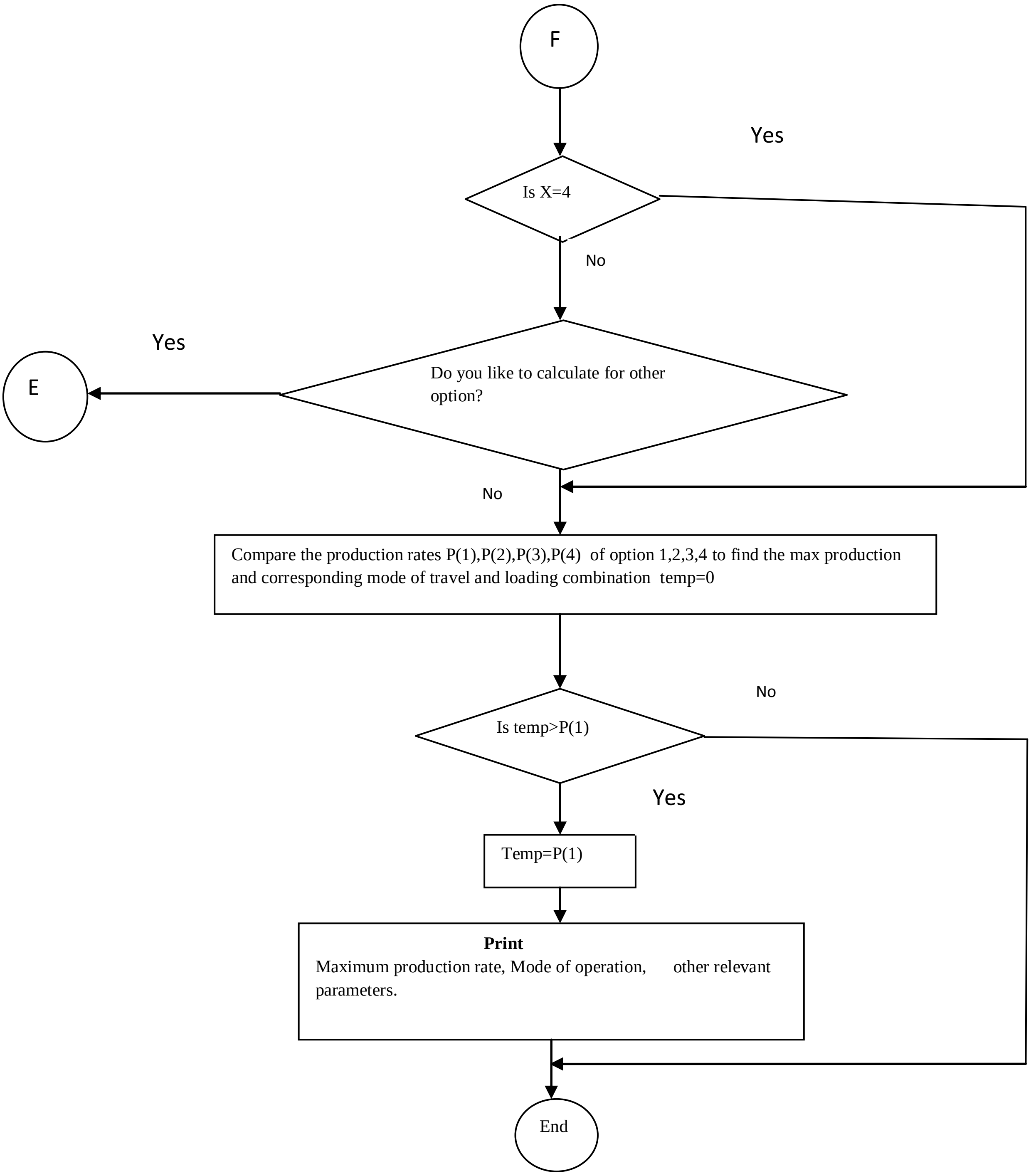


Fig. 4.1 - Flow charts for selection of optimum mode of operation

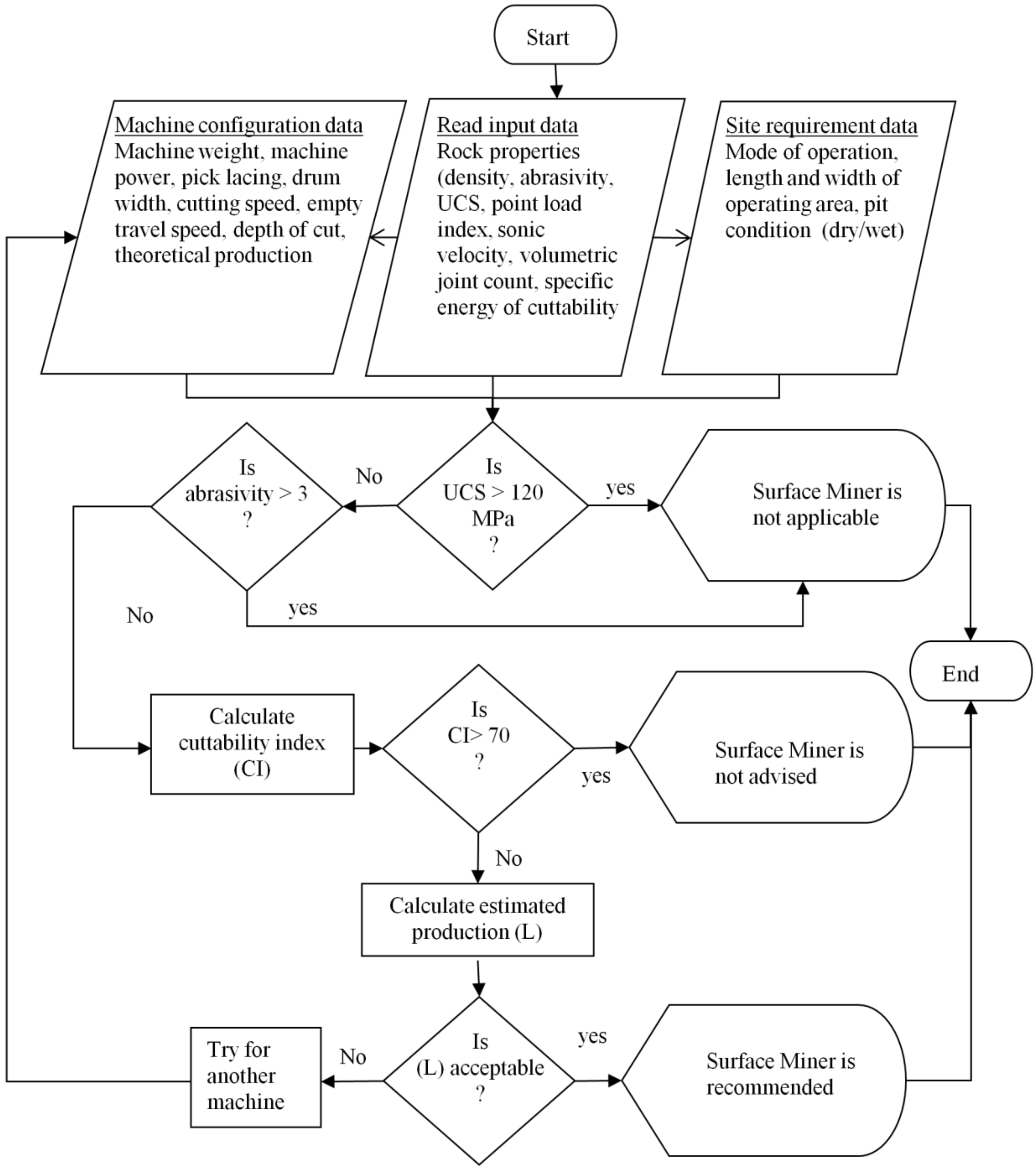


Fig. 4.2 - Flow chat for selection of surface miner based on cuttability index

4.2 NET BEANS [10]

Net beans refers to both a platform for the development of applications for the network (using Java, JavaScript, PHP, Python, Ruby, Groovy, C, and C++), and an integrated development environment (IDE) developed using the Net Beans Platform.

The **Net Beans Platform** is a reusable framework for simplifying the development of other desktop applications. When an application based on the Net Beans ide 6.5 [11] Platform is run, the platform's Main class is executed. Available modules are located, placed in an in-memory registry, and the modules' startup tasks are executed. Generally, a module's code is loaded into memory only as it is needed.

Applications can install modules dynamically. Any application can include the Update Centre module to allow users of the application to download digitally-signed upgrades and new features directly into the running application. Reinstalling an upgrade or a new release does not force users to download the entire application again.

The platform offers services common to desktop applications, allowing developers to focus on the logic specific to their application. Among the features of the platform are:

- User interface management (e.g. menus and toolbars)
- User settings management
- Storage management (saving and loading any kind of data)
- Window management
- Wizard framework (supports step-by-step dialogs)

4.3 THE SOFTWARE (S.M 1.0)

In the previous semester computer program was developed in C language to choose the optimum mode of operation. In this semester computer program can also check the applicability of the surface miner by the help of Cuttability index as discussed above. The computer program was tested with the help of real field data. To make the software more user friendly it is done with the help of Net Beans.

4.3.1 Designed model in C

The developed module can check the applicability of the surface miner and if it is applicable than it can select the optimum mode of operation and the production in that mode. This program was developed in C language which runs in dos mode.

The step by step procedure to use the software is as follows –

Step 1 : The basic information like rock properties and machine configuration has to give.

Step 2 : Check the UCS & abrasivity of rock than calculate the cuttability index.

Step 3 : Calculate the estimated production than check whether the production is acceptable or not. If not go for other model otherwise show the production.

Step 4 : To choose operating mode the basic inputs like machine parameters has to give and the calculation option for travel & loading combinations mode has to select.

Step 5 : Check the mode of travel & loading combinations inserted.

Step 6 : Read the relevant input parameters required for production analysis.

Step 7 : Calculate the production for the selected mode of travel and loading combination

Step 8 : Check and calculate for other modes.

Step 9: Compare the productions and find out the mode of maximum production and print.

The software has the feature to give the output in text format also.

4.3.1.1 A trial of the software

The software has been tested for a case of coal mines of MCL. The data are taken from Lakhanpur Opencast Project of Mahanadi Coal Fields Limited.

Point load index = 1.1 i.e. rating *Is* = 10

Surface Miner used == 2200 SM [5]

Rated machine capacity = 400 m^3/h

Machine power = 448 kW i.e. rating *Mc* = 16
Volumetric joint count = 32 i.e. rating *Jv* = 5
Abrasivity = 0.4 i.e. rating *Is* = 3
Direction of machine operation with respect to joint plane = 80º i.e. rating *Js* = 3
Thus, cuttability index (*CI*) = 37 **(thus very easy cutting condition for surface miner)**
Expected production (for k = 0.6) = (1 – 37/100) × 400 × 0.6 = 151 m3/h
Density = 1.4
Expected production achieved = 210 t/h
Truck exchange time=24 sec Length required to fill a truck = 51 m
Drum width=2.2m Cutting depth = 160mm

Cutting speed=22m/min Empty travel speed=25m/min

Turning time=4.6min Length of face=212m

Production for empty travel back & conveyor loading is=216.08 tonnes/hour

Production for empty travel back & windrowing is= 235.91 tonnes/hour

Production for turn back & conveyor loading is=268.81 tonnes/hour

Production for turn back & windrowing is=300.21 tonnes/hour.

4.3.1.2 Screen input and output page in dos mode

It allows the user to provide the input parameter one by one on a black screen, in case of mistake in between the user can reload the program by pressing the bottom "R/r" which will take the user to the first input data. After taking all the value the software can give the optimum mode of operation and the maximum production.

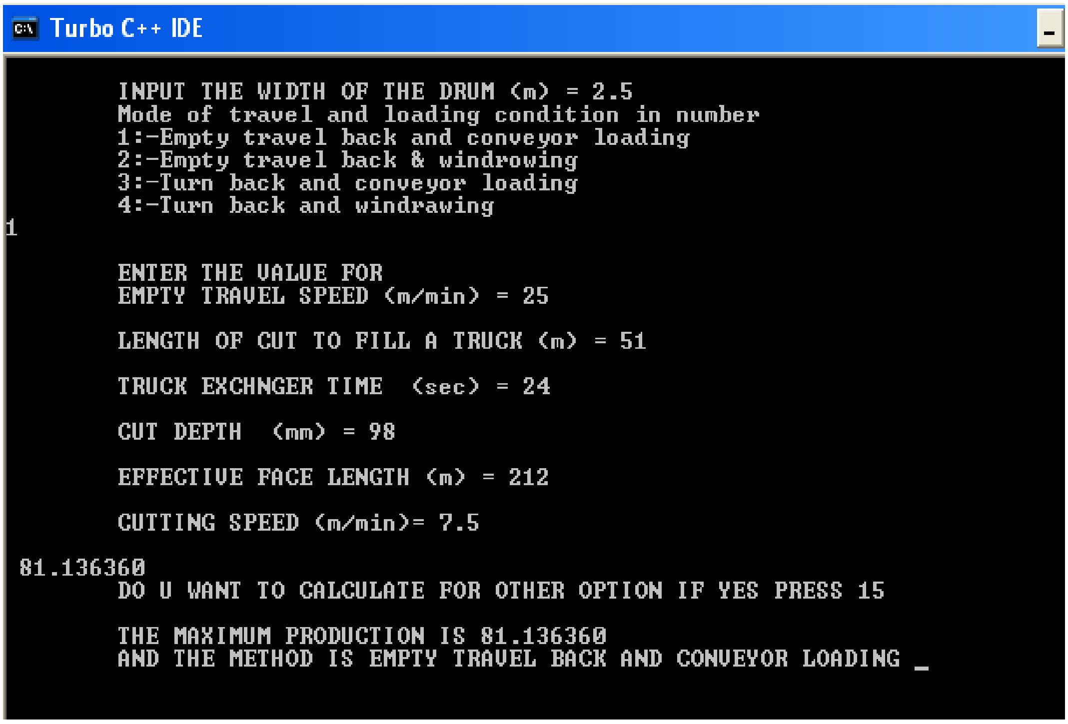


Fig 4.3 – input output page in dos mode.

<u>4.3.2 Design model In Net Beans</u>

4.3.2.1 STARTING SCREEN**:** it is the starting page (Fig. 4.4) which welcomes the user and asks the user to click the "Ok" button to continue, after pressing ok button it will take you to the machine input parameters page.

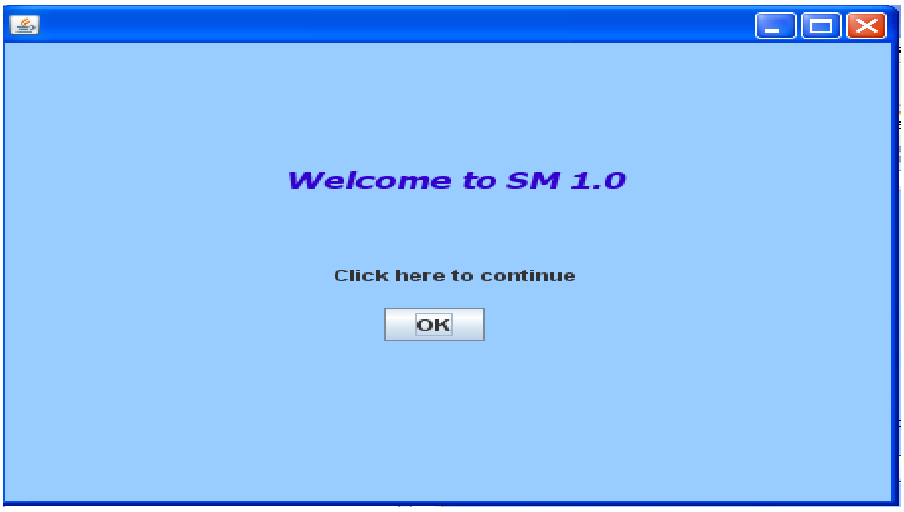


Fig. 4.4- Welcome page

4.3.2.2 MACHINE PARAMETERS

This page (Fig. 4.5) allows the user to select the company name and models. After choosing company name and model it will show the drum width, machine power, operating weight, rated capacity, cutting depth, maximum cutting speed, empty travel speed & operating gradient. Then it will go to the rock parameter page.

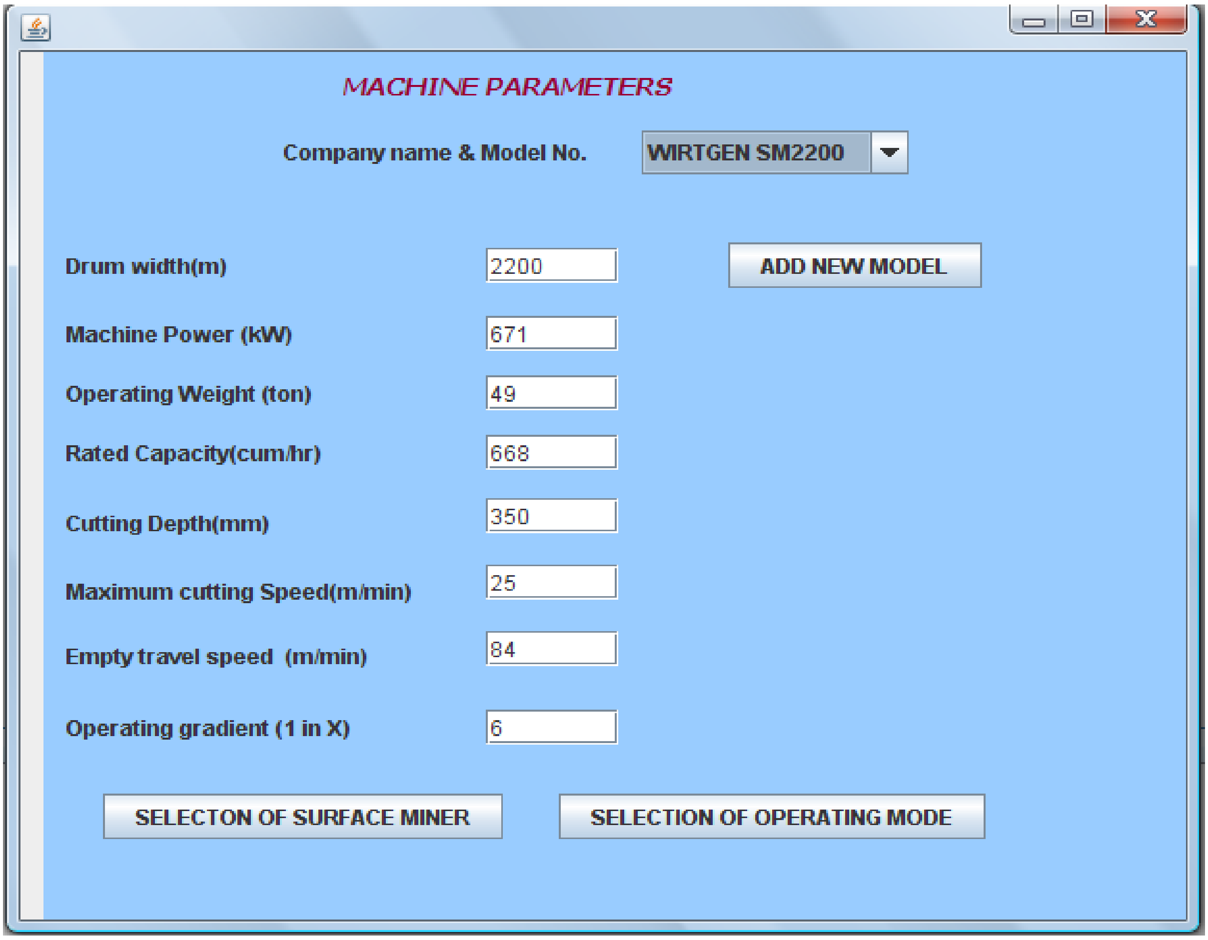


Fig. 4.5 - Machine Parameters page

Pop-up message box: if a user makes a mistake during input, a message will on the screen in red font which will show the error type and in which field so that user can change the data.

4.3.2.3 NEW MODEL

- If any model is not in the data base then the user can add a new model by clicking the new model option.
- In this page (Fig. 4.6) user can add a new model by giving all the data.
- After adding the new model the user can go for adding another model or can go to next step.

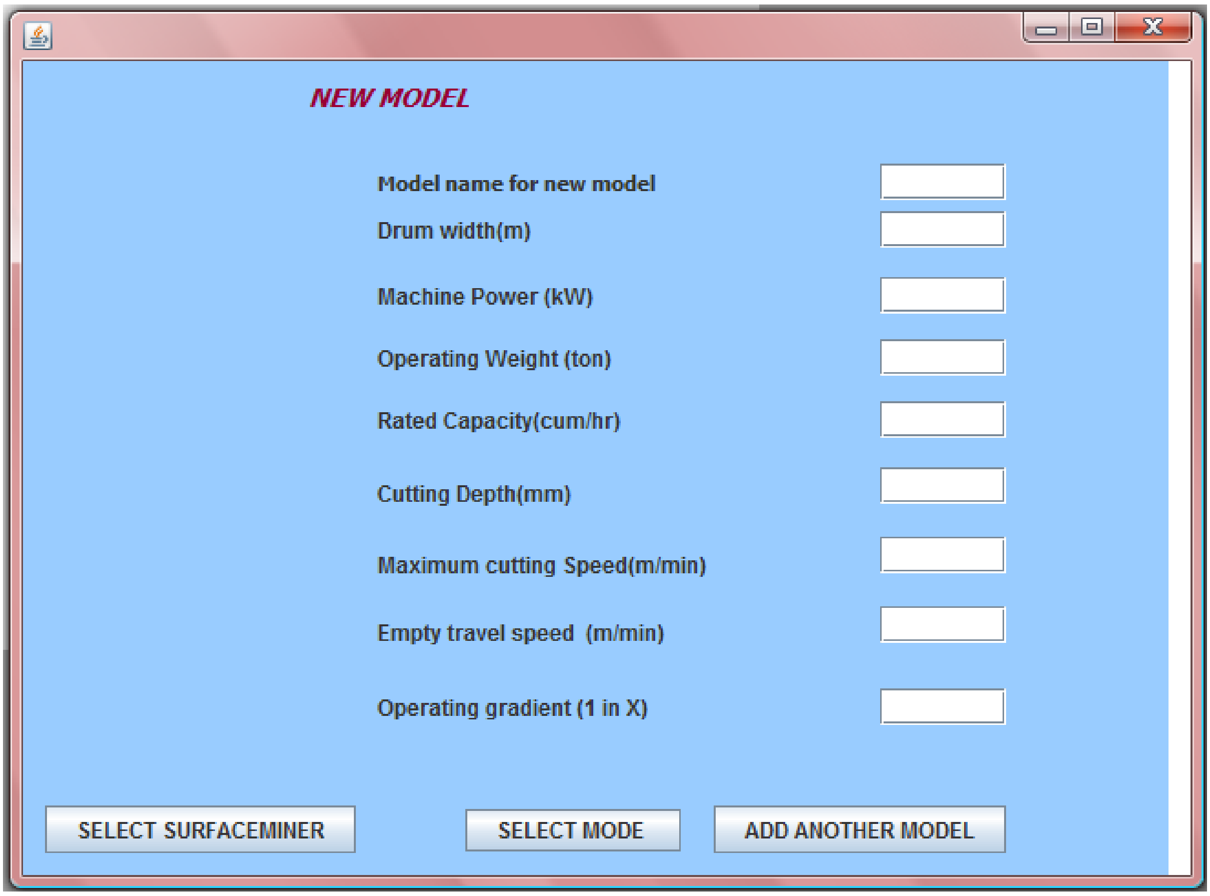


Fig. 4.6 -New model page

4.3.2.4 ROCK PARAMETERS

Rock parameters page (Fig. 4.7) will ask the user to input the required data such as UCS of the rock, point load index, volumetric joint count, abrasivity of the rock and direction cutting respect to major joint direction. After that it will calculate the cuttability index and check whether the surface miner is applicable or not.

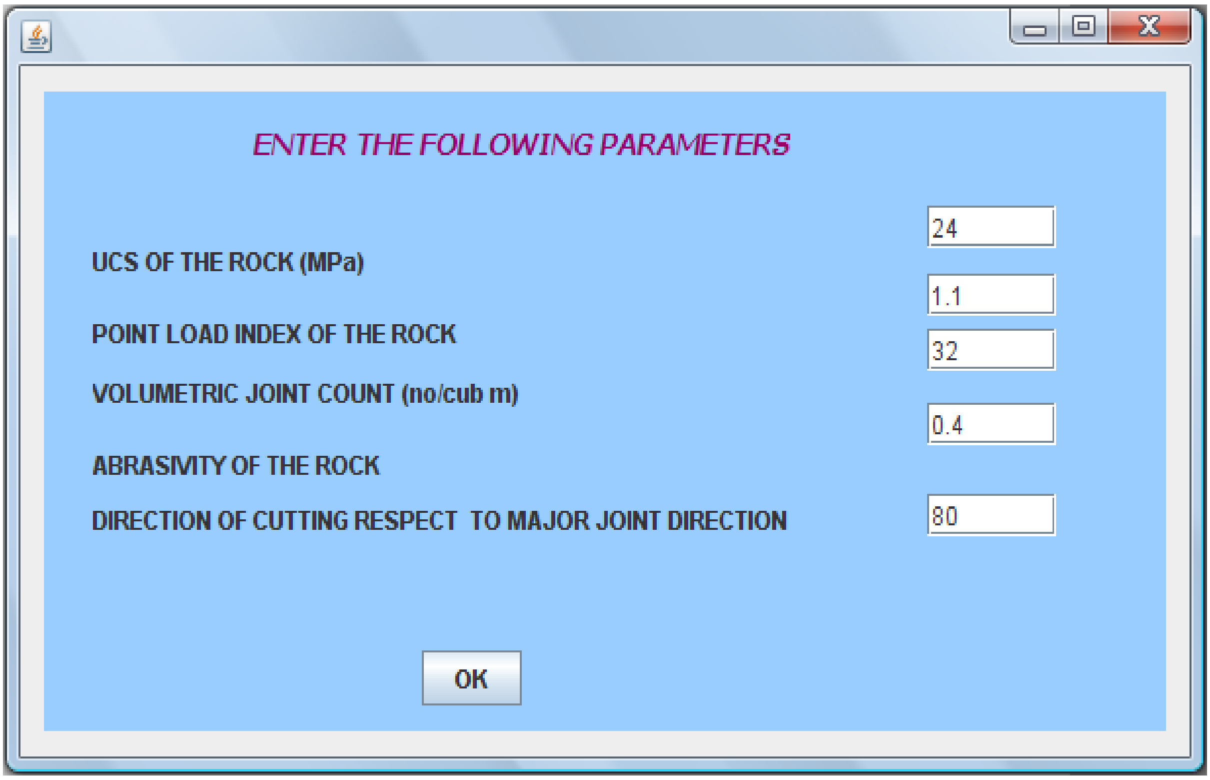


Fig. 4.7 -Rock Parameters page

4.3.2.5 CUTTABILITY INDEX

It will calculate the cuttability index and check whether the surface miner is applicable or not and accordingly show the message and the cuttability index. If this page (Fig. 4.8) will show not applicable than the user can choose to reinter the data by pressing home or can exit the program.

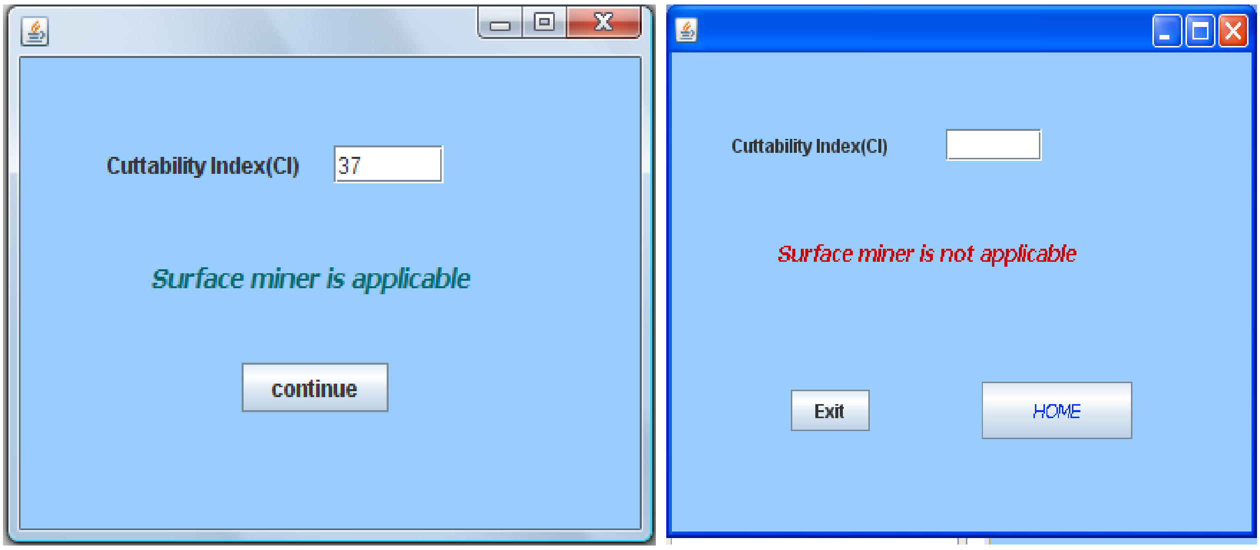


Fig. 4.8 -Cuttability Index

4.3.2.6 CALCULATION OF PRODUCTION

In this page (Fig. 4.9) the software will ask the user to give the value of factor consideration of influence of specific cutting condition (i.e k) and the density of the rock which is required for calculation of production. After giving the required data the user has to click the next button to go to the next page.

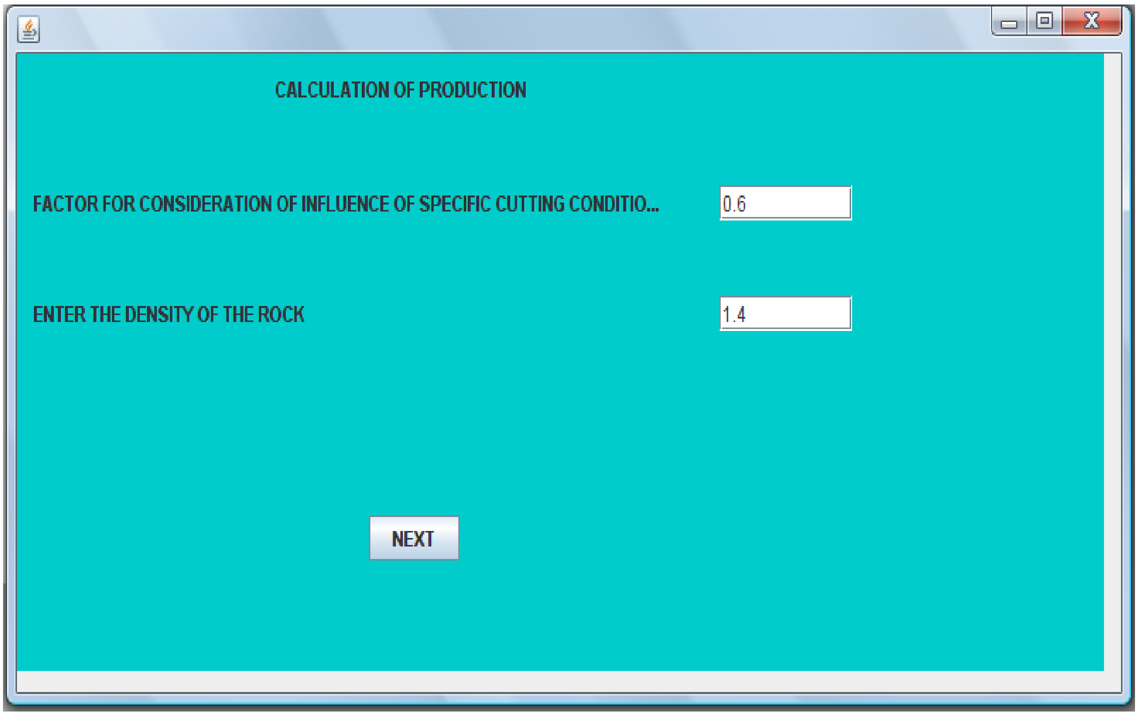


Fig. 4.9 -Calculation of Production

4.3.2.7 EXPECTED PRODUCTION

Expected production for the given condition is shown in this page (Fig. 4.10). The user has to choose whether the production is acceptable or not, if not acceptable then the user should choose to calculate for another machine, and if the production is acceptable then the user should click continue button. If the user click the continue button then the software open the selection of mode of operation page. If the user click the calculate for another machine button then the software open the selection of machine page.

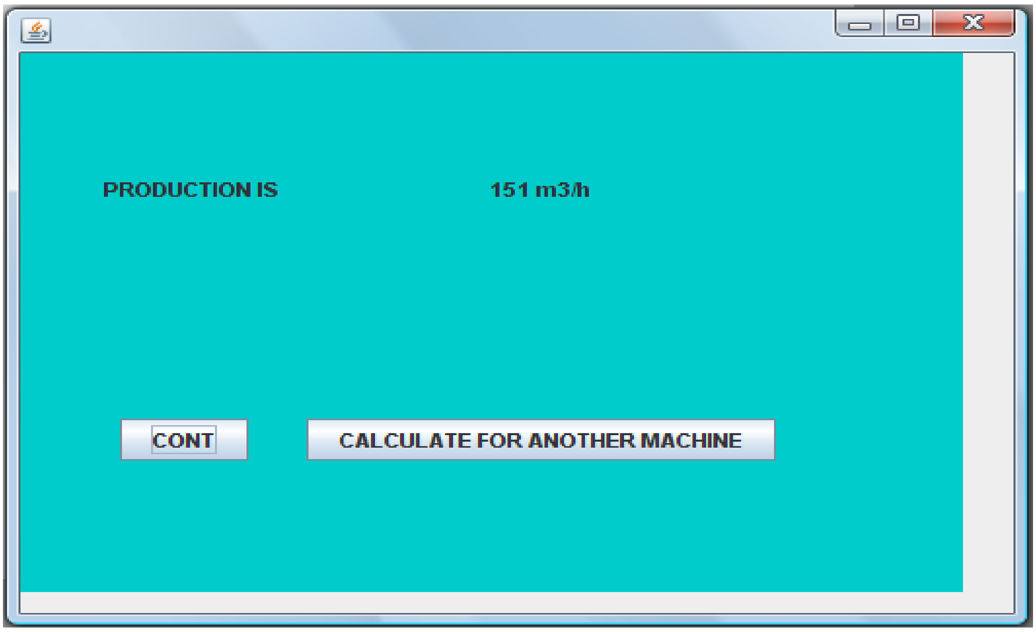


Fig. 4.10-Expected Production

4.3.2.8 SELECTION OF MODE OF OPERATION

In selection of mode of operation page (Fig. 4.11) the user has to choose one mode of operation and he should click the ok button to go to the next page.

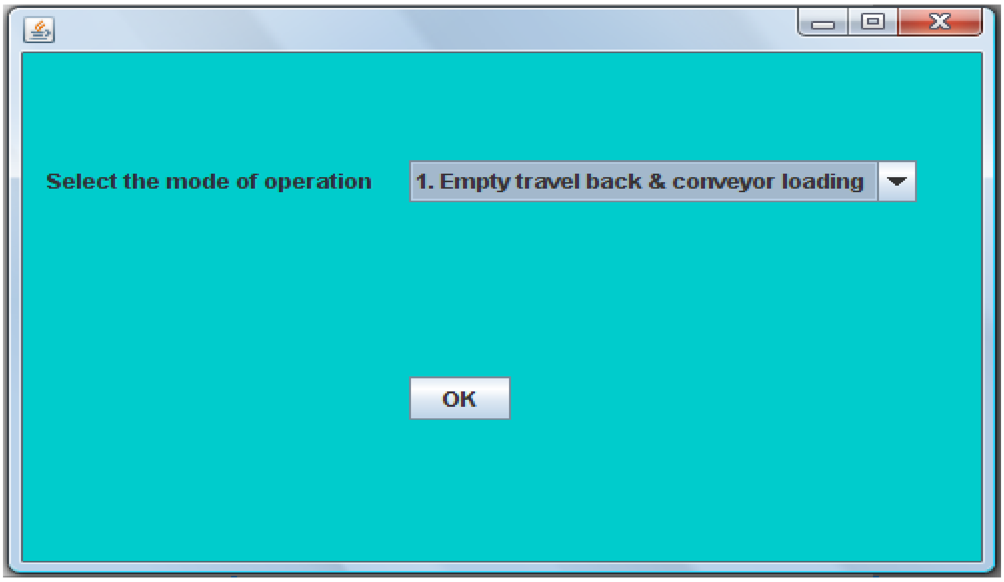


Fig. 4.11 -Selection of Mode of Operation

4.3.2.9 EMPTY TRAVEL BACK AND CONVEYOR LOADING

If the user chooses empty travel back and conveyor loading option in the selection of mode of operation page then empty travel back and conveyor loading page (Fig. 4.12) will come. In this page the software ask to give some data which are required for calculation of production. To see the production the user has to click the calculate button.

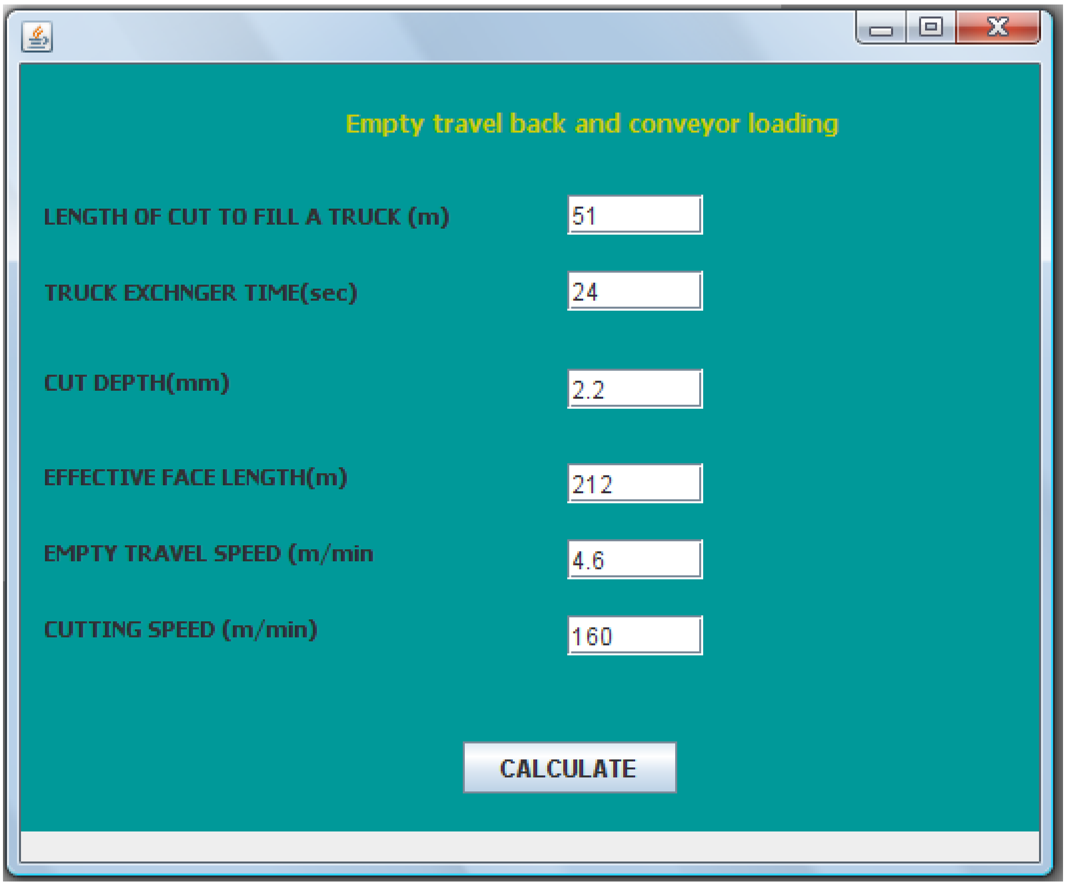


Fig. 4.12 -Empty Travel Back and Conveyor Loading

4.3.2.10 PRODUCTIONS FOR DIFFERENT MODE

In this page (Fig. 4.13) the user can see the production for all the mode of operation. In left side the user can see the name of mode of operation and in right side the production in that mode and if production is not calculated for any mode then the software will shoe NC (not calculated). The user can also choose to calculate the production for different by clicking the "Calculate production for different mode" which will take the user to the selection of mode of operation page.

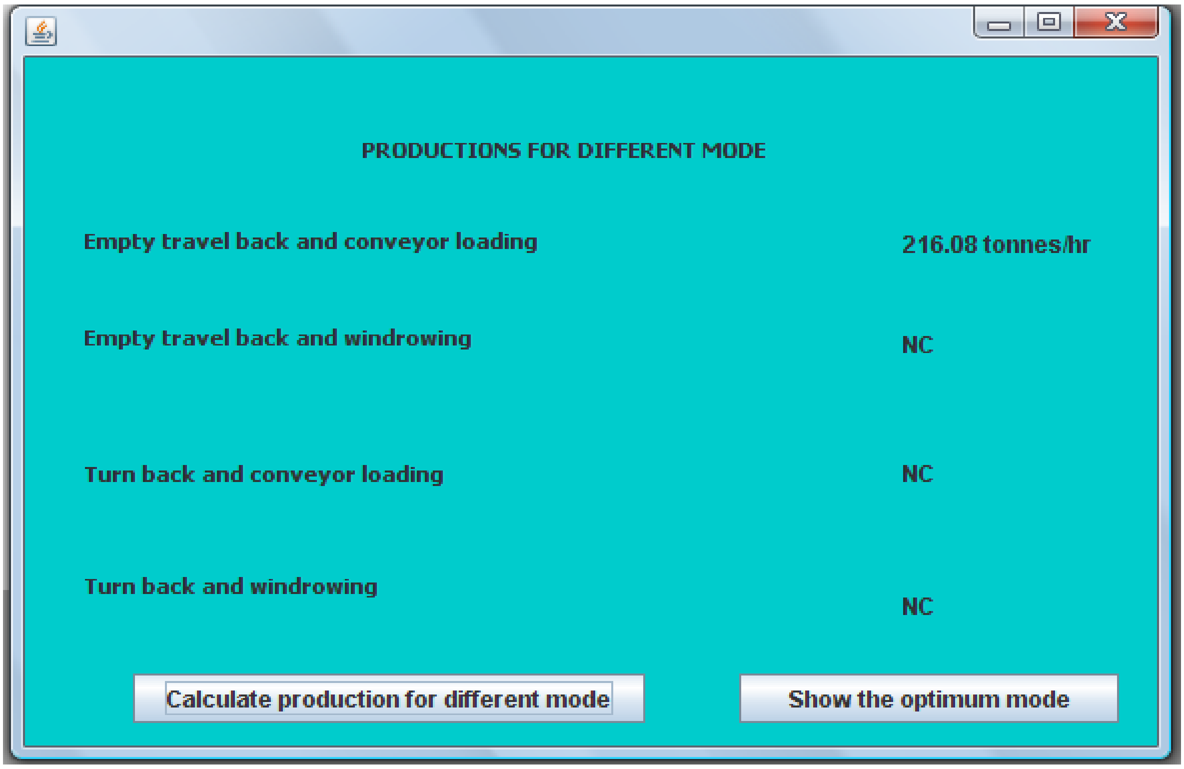


Fig. 4.13 -Productions for Different Mode

4.3.2.11 EMPTY TRAVEL BACK AND WINDROWING

If the user chooses empty travel back and windrowing option in the selection of mode of operation page then this page (Fig. 4.14) will come. In this page the software ask to give some data which are required for calculation of production. To see the production the user has to click the calculate button.

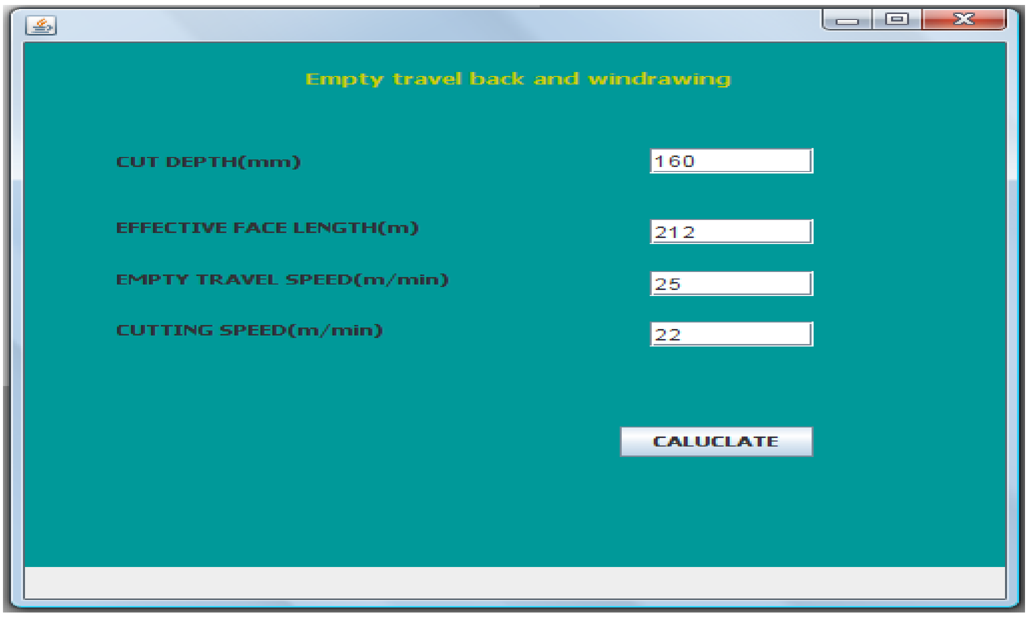


Fig. 4.14 -Empty Travel Back and Windrowing

4.3.2.12 TURN BACK AND CONVEYOR LOADING

If the user chooses Turn back and conveyor loading option in the selection of mode then this page (Fig. 4.15) will come. In this page the software ask to give some data which are required for calculation of production. To see the production the user has to click the calculate button.

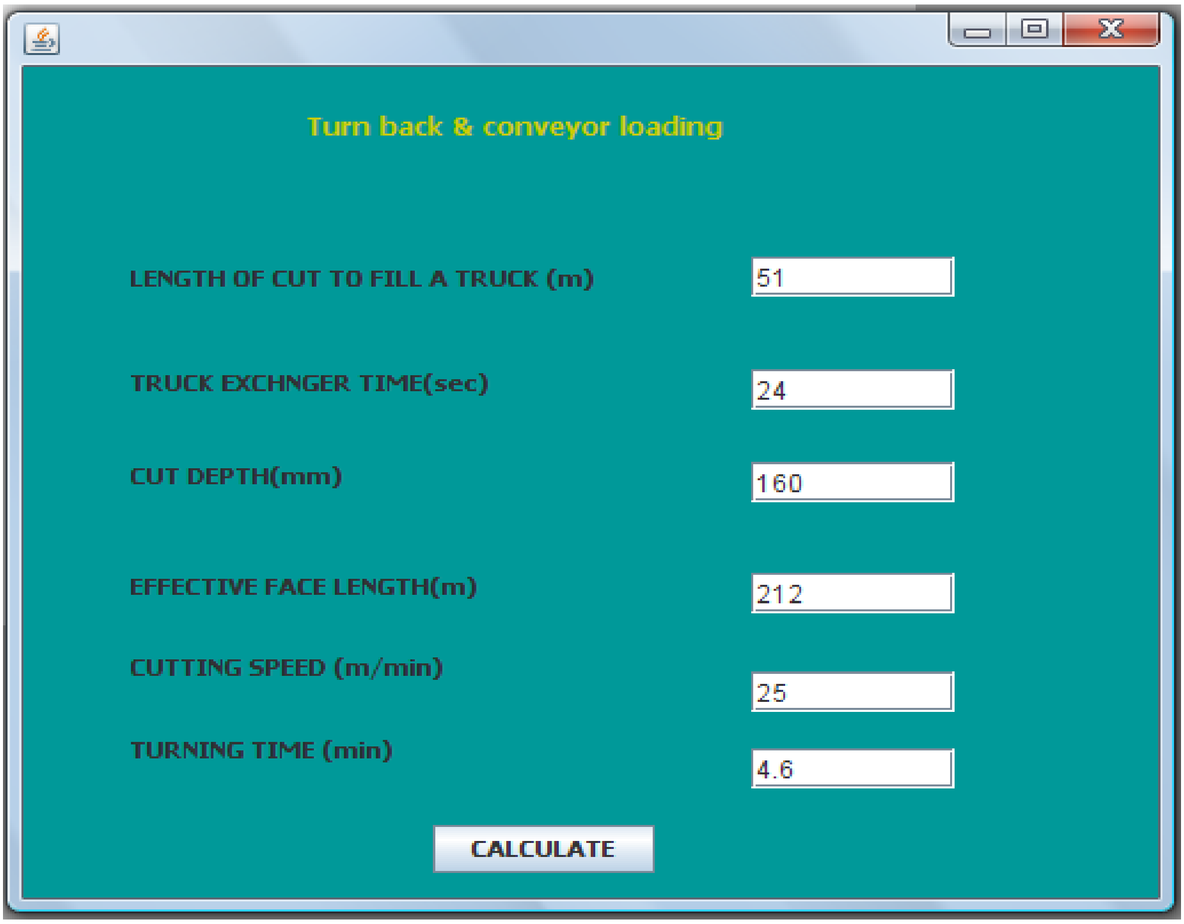


Fig. 4.15 - Turn Back and Conveyor Loading

4.3.2.13 TURN BACK & WINDROWING

If the user chooses Turn back & windrowing option in the selection of mode of operation page then turn back & windrowing page (Fig. 4.16) will come. In this page the software ask to give some data which are required for calculation of production. To see the production the user has to click the calculate button.

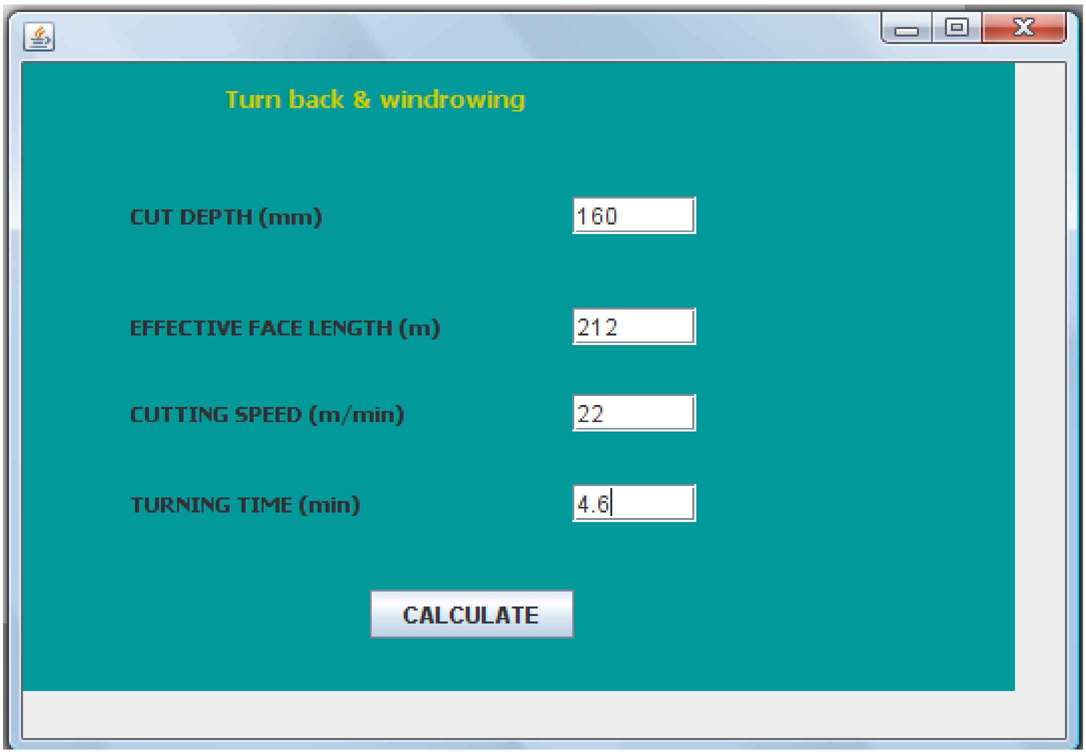


Fig. 4.16 - Turn Back & Windrowing

4.3.2.14 RESULT PAGE

In result page (Fig. 4.17) the software will show the optimum the mode of operation along with the optimum production. If the user want to select the surface miner or the mode of operation for another mine he can click the home button which will take the user to the machine parameter page otherwise he can click exit button to exit the software.

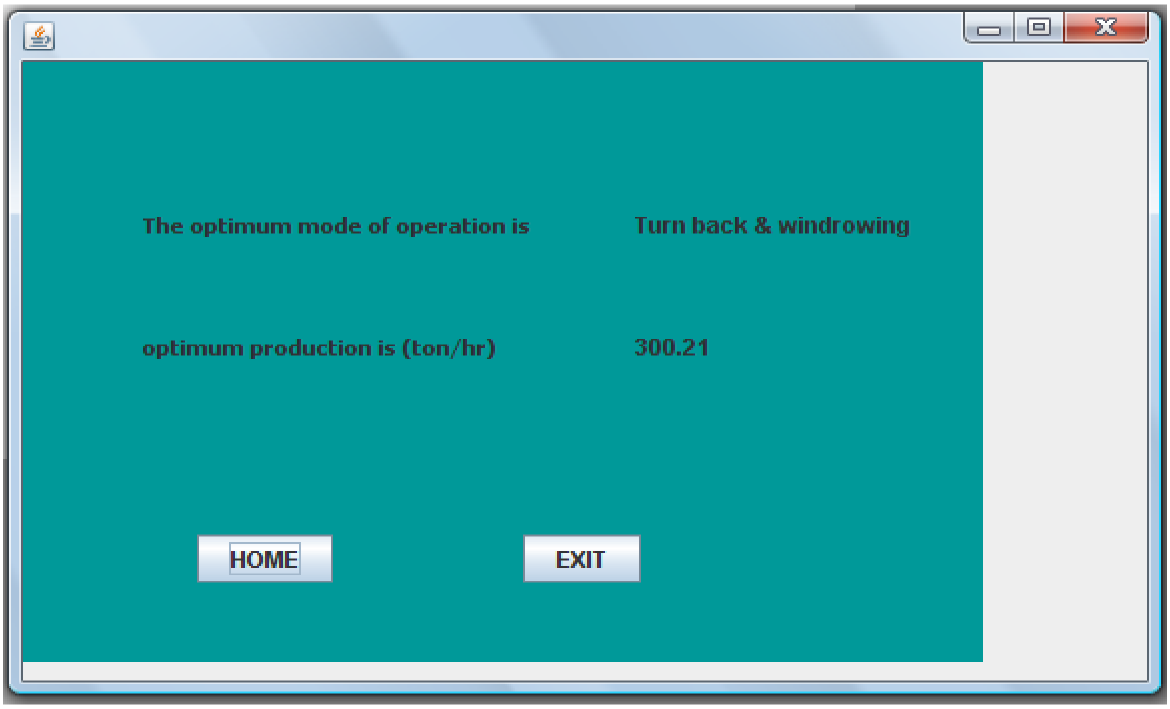


Fig. 4.17 - Result Page

CHAPTER: 05

RESULT & DISCUSSION

FUTURE WORK

CHAPTER: 05

RESULT & DISCUSSION

5.1 Result & Discussion:

Different parameters to be considered for selection of surface miner and optimum mode of operation have been reviewed extensively. The key parameters having significant influence on selection of surface miner and optimum mode of operation are identified. The key parameters of different types of models which were available in the market have been collected. The different types of surface miner manufacturer are Wirtgen, Vermeer, L & T, TAKRAF, and Bitelli. Among these the most popular one is Wirtgen. Some of the manufacturers (like Wirtgen) are providing their production chart for different modes as well as for different models. But these charts are based on ideal condition which is very much greater than actual production. The selection of surface miner and optimum mode of operation concept is very complex and needs larger time for hand calculation. So, it was felt to establish a user friendly computer program to assist the field engineer to arrive at the optimum mode of operation and production calculation which is the one of the important part of daily planning. It is also need to check before deploying any surface miner whether the surface miner is applicable to the condition or not.

The developed software is user-friendly and easy to operate. Thus, it can be used to select the suitable surface miner model and also the optimum mode of operation. Software may suggest a mode of operation as the optimum (windrowing in this case). As the software is developed based on the empirical relationship, the software has limited utilization. However, for the new model the database should be modified by user. In this software the input has to be provided through keyboard and the input & output can be seen on the program itself. The software is using many important parameters like rock parameter, and machine parameter and operating condition. The software has been tasted in two mines; one coal mine in Orissa and a limestone mine in south India. The calculated production may not be same as actual production because it also depends on the skills of the operators, accuracy of field data, and performance of the machine.

To make it more user friendly the software was designed & modified by net beans. A data base is also available with the software to make it more user friendly, useful and less time consuming. It is strongly recommended to carry out financial analysis prior to deployment of surface miner. In future, all those (including financial assessment would be given in a nutshell in the software.

5.2 Future work

- This software is not applicable for continuous mode operation. The software may be modified to calculate the production for continuous mode.
- In future, all the financial assessment would be given in a nutshell in the software.

CHAPTER: 06

REFERENCE

CHAPTER: 06

REFERENCE

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DEVELOPMENT OF A COMPUTER PROGRAM FOR SELECTION OF OPTIMUM MODE OF OPERATION FOR SURFACE MINER

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Introduction:

Surface miners find their natural applications in projects where drilling and blasting is prohibited or selective mining of mineral, partings and overburden is required. It also offers further advantages like less coal/mineral loss and less dilution, improved coal/mineral recovery with improved quality and finer fragment size which eliminates crushing. Surface miner can work in mining of limestone and coal with competitive cost if deployed judicially. The productivity of surface miner largely depends on the rock properties, machine configuration and application of surface miner. The rock properties are immutable and the machine configuration is one time decision of the higher management. Thus, mining engineer has to operate surface miner judicially to achieve the maximum production. In this paper, the development of computer software is presented, which helps mining engineer for selecting the surface miner based on cuttability index and the optimum mode of operation.

Objective:

The basic objective of the project is to develop a computer program for selection of optimum mode of operation for surface miners and to check whether surface miner is applicable or not.

Methodology:

"Cuttability index" developed has been utilised in selection of surface miner model, it considered the key influencing parameters, namely, point load strength index, rock abrasivity, volumetric joint count, direction of machine operation with respect to joint direction and the cutting power of surface miner. The ratings of these parameters are used in calculation of cuttability index. the cuttability index (*CI*) is the sum of the rating of above five parameters

$CI = I_s + Jv + Aw + J\,s + M$

This cuttability index gives a firsthand idea about the "GO – NO GO" criterion on applicability of surface miner. Production rate of a surface miner can be estimated as follow –

$$L^* = \left(1 - \frac{CI}{100}\right) k M_c$$

Where,

L^* = production or cutting performance (bcm/h)

Mc = Rated capacity of the machine (bcm/h)

CI = cuttability index

k = a factor for consideration of influence of specific cutting condition and is a function of pick lacing (array), pick shape, atmospheric condition etc. and varies from 0.5 – 1.0.

Similarly, the mathematical relationship proposed for computation of surface miner performance in different operating mode is utilised for selecting the optimum operating mode of surface miner.

- Empty travel back & conveyor loading $p = \frac{S \times D}{1000}\left(\frac{60}{1/_{Vc} + 1/_{Ve} + Tc/_{Lt}}\right)$
- Empty travel back & windrowing $p = \frac{S \times L \times D}{1000}\left(\frac{60}{L/_{Vc} + L/_{Ve}}\right)$
- Turn back & conveyor loading $p = \frac{S \times D}{1000}\left(\frac{60}{1/_{Vc} + Tt/_{L} + Tc/_{Lt}}\right)$
- Turn back & windrowing $p = \frac{S \times L \times D}{1000}\left(\frac{60}{L/_{Vc} + Tt}\right)$

Where S=Drum width, Lt=Length of cut to fill a truck, Tc=Truck exchange time, D=Cut depth, L=Effective face length, Vc=Cutting speed, Tt=Turning time, Ve=Empty travel speed.

Utilising these theories and the formula software has been developed in C and Net Beans(java platform) which can select the suitable surface miner model as well as optimum mode of operation and it displayed the optimum mode along with the production.

Result & Discussion

Different parameters to be considered for selection of surface miner and optimum mode of operation have been reviewed extensively. The key parameters having significant influence on selection of surface miner and optimum mode of operation are identified and .software has been developed with the help of C and Net Beans. The developed software is user-friendly and easy to operate. Thus, it can be used to select the suitable surface miner model and also the optimum mode of operation. A data base is also available with the software to make it more user friendly, useful and less time consuming. The database contains all the surface miner models available in the market. The software is smart enough to catch if the user makes any mistake. The software has been successfully tested in two mines; one coal mine in Orissa and a limestone mine in south India. It is strongly recommended to carry out financial analysis prior to deployment of surface miner. In future, all those (including financial assessment would be given in a nutshell in the software

Reference:

1. Dey K. and Ghose A. K. (2008), *Predicting "Cuttability" with Surface Miners – A Rockmass Classification Approach*, Journal of Mines, Metals and Fuels, Vol.56 No.5 & 6 May – June, pp 85 - 92.
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